YOUR OFFICIAL **RASPBERRY PI** MAGAZINE

The MagPi

The official Raspberry Pi magazine

Issue 65 January 2018

raspberrypi.org/magpi

APHEX TWIN MIDIMUTANT
Megastar talks to us about new AI music tool

RASPBERRY PI FOR NEWBIES

- Set up and start using your Raspberry Pi
- Find help from the community
- Discover clubs, meet-ups & other enthusiasts

MAKE GAMES IN C++
Professional video game development

PI-TOP LAPTOP REVIEWED!
The pro laptop with Pi inside

RING IN THE NEW YEAR
Build a ringing bell tower

VISION KIT
Image recognition for your projects

Also inside:

- **BUILDING A SMART BABY MONITOR**
- EASY TRAFFIC LIGHTS WITH PI TRAFFIC HAT
- **CREATE WEARABLES WITH BEARABLES KITS**
- MANAGE RASPBERRY PI BOARDS WITH PISERVER

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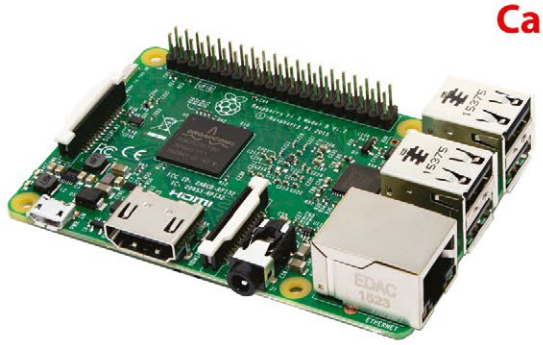

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WELCOME TO THE OFFICIAL MAGAZINE

Happy new year! Every January, we welcome a huge number of brand new Raspberry Pi users. So come on in, take a seat, and don't mind the robots (they don't normally bite).

First of all, have you seen our new Raspberry Pi for Newbies feature (**page 16**)? It's the perfect welcome for newcomers. You see, the Raspberry Pi community is massive. Our calendar is packed with events, like Pi Jams, Formula Pi, and Pi Wars.

Raspberry Pi isn't just a computer and a charity. We're a community of people who love making stuff with programmable computers. So if you want to learn about digital making with Raspberry Pi, then you've found the right place.

And for all you regulars... Don't worry! We have a magazine packed with project ideas, and a big look at AIY Projects: Vision Kit (**page 62**). Discover how to set it up, add smart vision to your projects, and how artificial neural networks are created.

We go from welcoming newcomers to building artificial neural networks. How neat is that?

Lucy Hattersley
Editor

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Raspberry Pi PRESS

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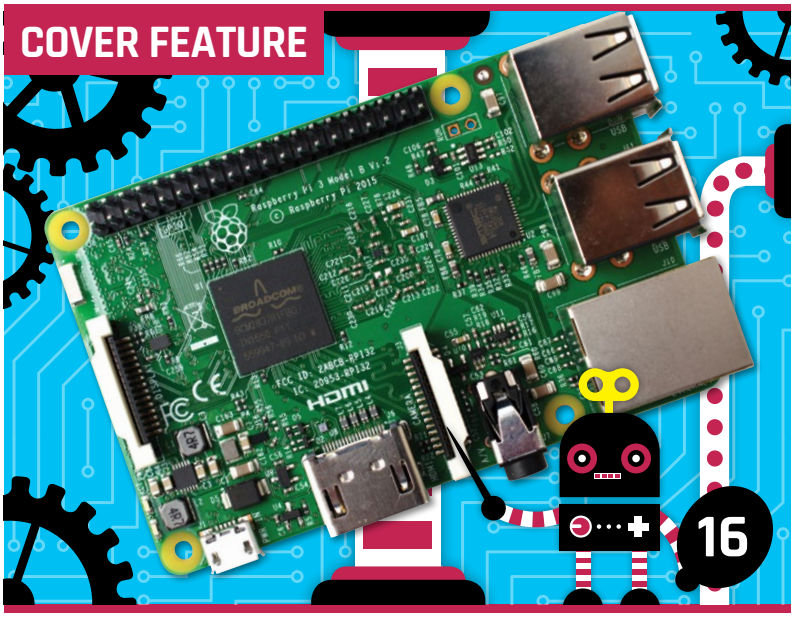

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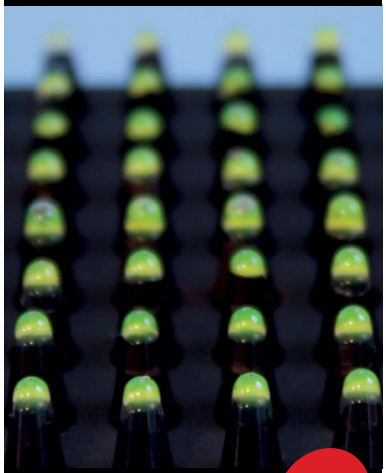

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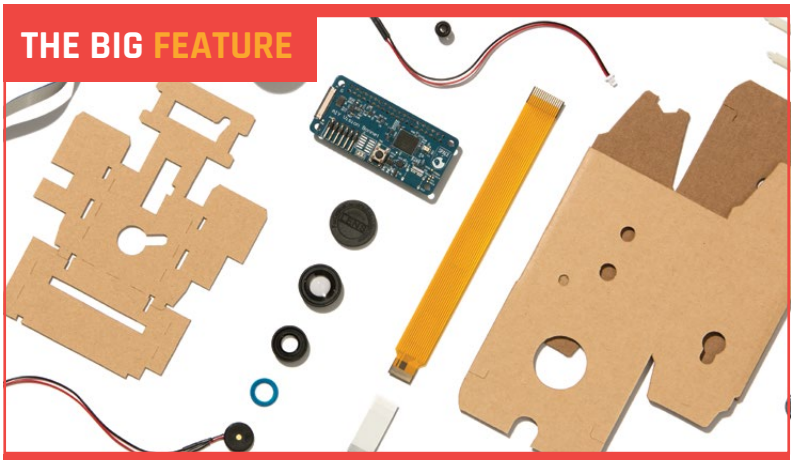

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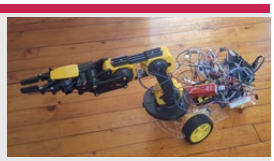

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PI-POWERED AI TEASMADE

STARS IN CHANNEL 4 SHOW

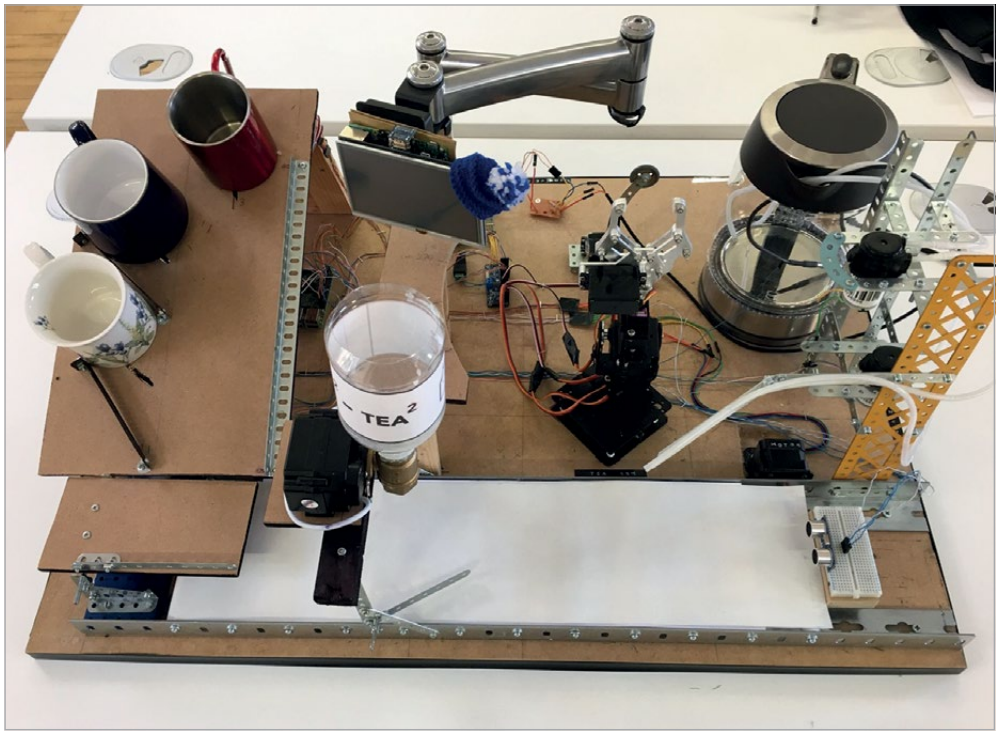
Smart teasmade built using Raspberry Pi features in Channel 4 show: Guy Martin Versus the Robot Car

A Raspberry Pi was taken for a test run by speed junkie Guy Martin in Channel 4's recent documentary, Guy Martin Versus the Robot Car.

The Pi powered tea-making robot, ingeniously named R2-Tea2, was designed and built by Huddersfield's Running in the Halls (RITH), a design and development studio whose "primary focus is designing and developing web and mobile apps, games and installations" according to RITH co-founder and director, Sam Croft.

RITH's brief was "to demonstrate how AI could be used in technology that is readily accessible to anyone that has an interest in physical computing," Sam tells us.

> "Guy doesn't have a smartphone and uses a 15-year-old Nokia. This limited our chatbot idea to using SMS text messages"



Below R2-Tea2 not only uses and understands natural language, but uses AI to select the correct mug, tea, milk content, and brew time

The idea to make a teasmade came from Guy's love of tea, with the aim that Guy could interact with the robot tea-maker "through some kind of chatbot that would make decisions, based on his [Guy's] responses in the conversation, about what kind of tea to make," Sam explains.

However, Sam reveals that "Guy doesn't have a smartphone and uses a 15-year-old Nokia. This limited our chatbot idea to using SMS text messages."

Robo-tea

R2-Tea2 has "two core components," Sam continues: "The making robot [and] the chatbot, with language processing and basic AI." The actual robot was based around the Pi, hooked up to a £12 Adafruit 16-channel PCA9685

Guy Martin and RITH's Alison Cox filming the show

PWM/servo driver board and two dual H-bridge motor drivers. As "the budget wasn't huge" for R2-Tea2, components needed to be cheap or easily sourced.

"We had one script [to control the robot] that sequenced the firing off of all the separate control scripts, which were nothing more complex than sending high and low signals to the correct pins with the correct delays," recalls Sam.

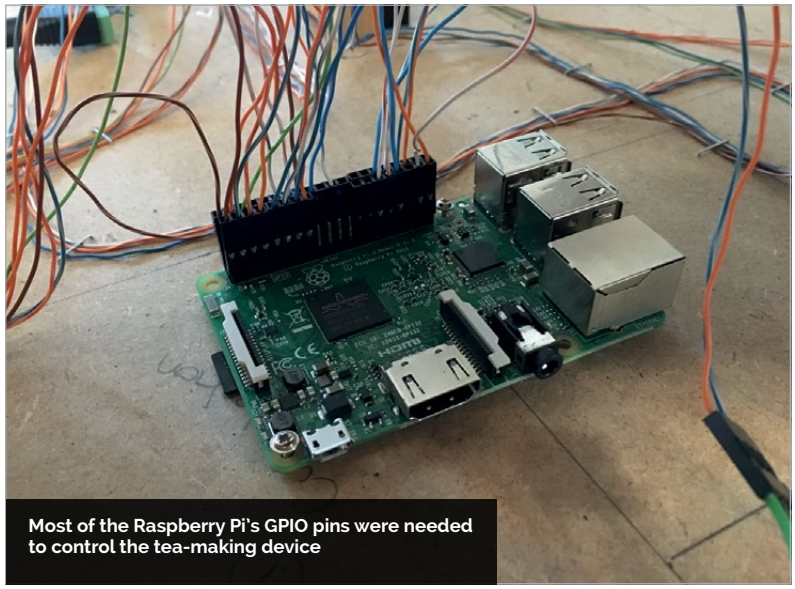
Look north

It was important that R2-Tea2 could understand Guy's "famous Northern turn of phrase," as Sam puts it, so the language-processing element was programmed to comprehend some of Guy's more unusual idioms.

RITH used Twilio (**twilio.com**) to handle the SMS messaging, and Google Dialogflow for the conversational interface. RITH then needed a webhook to send texts from Guy's phone to a Python application running on the Raspberry Pi. "To achieve this," Sam explains, "we had to expose our localhost server to the internet by using a service called ngrok." See **ngrok.com** for details.

The AI also analysed Guy's day to "approximate his current stress level". Blending SMS conversation and Guy's activities, R2-Tea2 chose "what kind of cup to use, which kind of tea, how much (if any) milk, and how long the tea should brew for," Sam reveals.

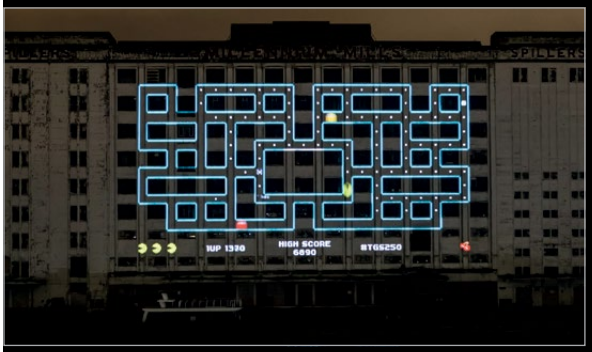
R2-Tea2 was built by two people at RITH: co-founder and director Alison Cox built the robot and the Python script while Sam built the chatbot portion.



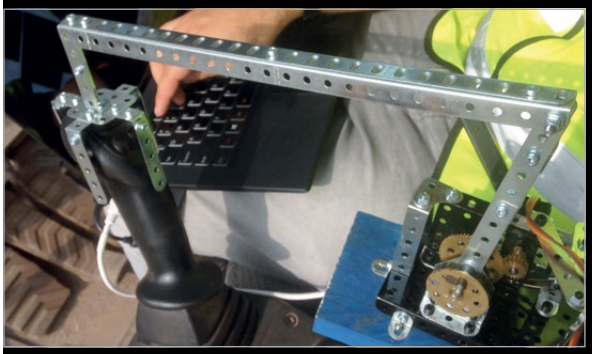
Most of the Raspberry Pi's GPIO pins were needed to control the tea-making device

ALSO BY RITH

Well-known gadgeteer Stephen Fry was invited to play Battleships with a custom RITH build for Channel 4's *Gadget Man* show. The board was the side of a derelict building, projected onto from London's ExCeL exhibition centre. "This was a multiplayer, crowd-based game," RITH Partner Sam Croft tells us, "that anyone in the area could play."



"We worked with Bandai Namco," Sam says, to make a Pac-Man game for Channel 5's *The Gadget Show* "that fitted around the windows of the Millennium Mills building" near ExCeL. The project was awarded (and still holds) a Guinness World Record for largest architectural projection-mapped game. at 218.65m².



RITH developed "a solution for controlling a full-size digger with a Nod ring," a gestural controller that fits on the finger, for *The Gadget Show*. "We created a simple servo-driven arm controlled by computer to interpret the signals coming from the ring," Sam explains. "The digger arm essentially followed the movement of the user's arm."

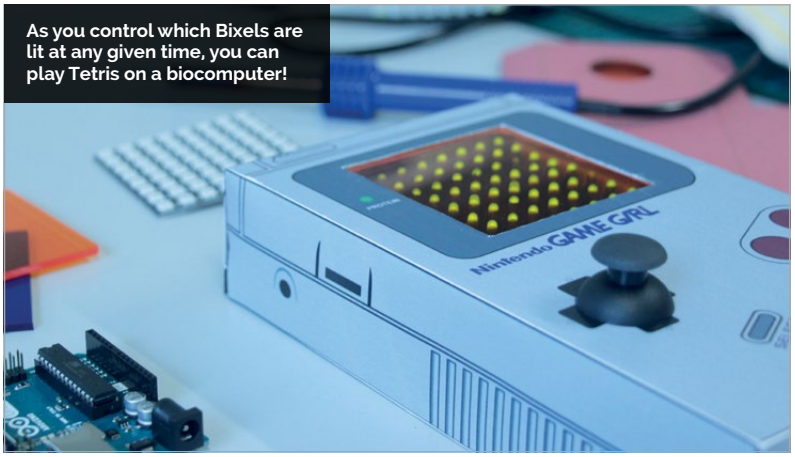
BIXELS: THE BIOCOMPUTING DISPLAY

Irish firm using DNA to play Tetris

Irish bio-tech firm Cell-Free Technology has launched a Kickstarter campaign for a "world-first demonstration of a DNA programmed bio-computer that can play Tetris".

Bixels is an 8×8 grid of 'bio-pixels' that can be controlled from a smartphone. As you can electronically control which Bixels are lit, the Bixels act just like the pixels in your screen.

The DNA is synthetically replicated from the same DNA that allows a jellyfish to glow green – no jellyfish are harmed to make Bixels.



As you control which Bixels are lit at any given time, you can play Tetris on a biocomputer!

> "Bixels incorporates almost every aspect of a STEAM curriculum in a single workshop"

Cell-Free Technology CEO Dr Thomas Meany tells us, "Bixels is a hugely valuable resource for anyone who needs a low-cost way to study fluorescent proteins in a lab, but our real target is STEAM educators." As Thomas points out, Bixels "incorporates almost every aspect of a STEAM curriculum in a single workshop."

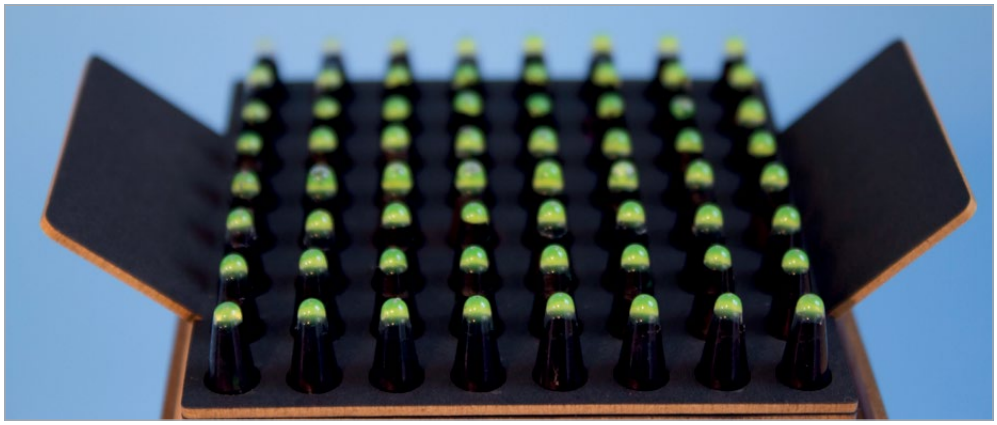
DNA for the masses

Bixels places an 8×8 grid of small test tubes (called PCR tubes) onto an 8×8 grid of RGB NeoPixels (controlled by an Adafruit Bluefruit Feather). By mixing the liquid in the two coloured vials of the kit in each PCR tube, you create a mixture that emits green when the NeoPixel beneath shines blue.

Or, as Thomas explains (very patiently), "The blue vial contains cell-free extract which has the nano-machinery (ribosomes, RNA polymerase, and transcription factors) that, when the DNA is added, can be programmed to produce a protein (in our case fluorescent protein)". A coloured filter within the Bixels housing ensures only the light emitted by the protein is seen.

Bixels is safe to play with and use because of the unique 'cell-free' technology developed by Cell-Free Technology. The 'bacteriophage infection' used breaks down cell walls without harming the contents, leaving you with a liquid that can be biologically programmed "without the fear of a bacteria or other organism [forming]," confirms Thomas.

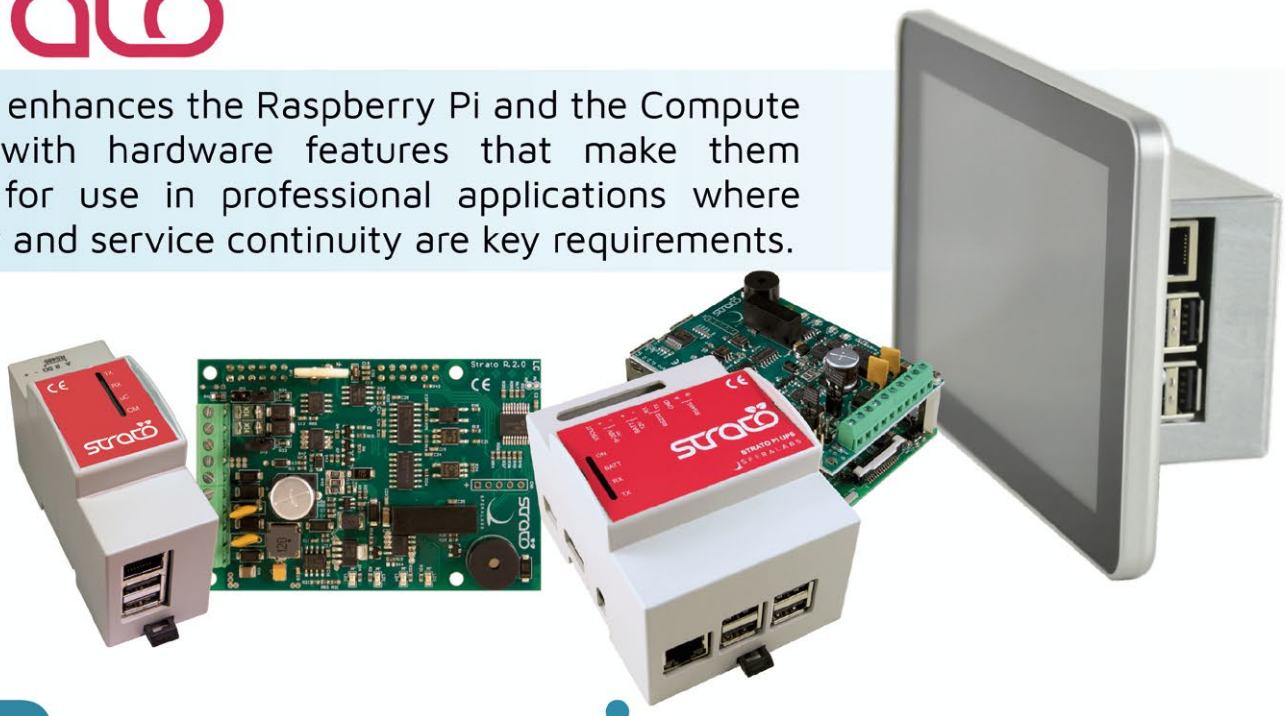
Bixels has a target of €9267 (£8166), with a basic Bixel Solo kit only costing €90 (£79).
See **kck.st/2BwjZyc**.



Below Mix actual DNA with a special 'cell-free' liquid in each test tube to create a light-emitting protein

Raspberry Pi for professional applications

Strato Pi enhances the Raspberry Pi and the Compute Module with hardware features that make them suitable for use in professional applications where reliability and service continuity are key requirements.



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- CAN BUS
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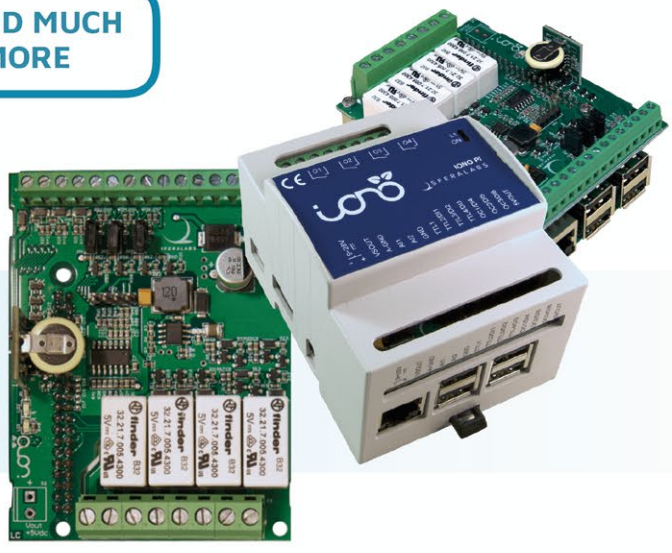
- WIDE RANGE POWER SUPPLY
- MODBUS
- .. AND MUCH MORE

Iono Pi is a versatile I/O module that combines digital and analog standard interfaces with the powerful computing core of the Raspberry Pi.



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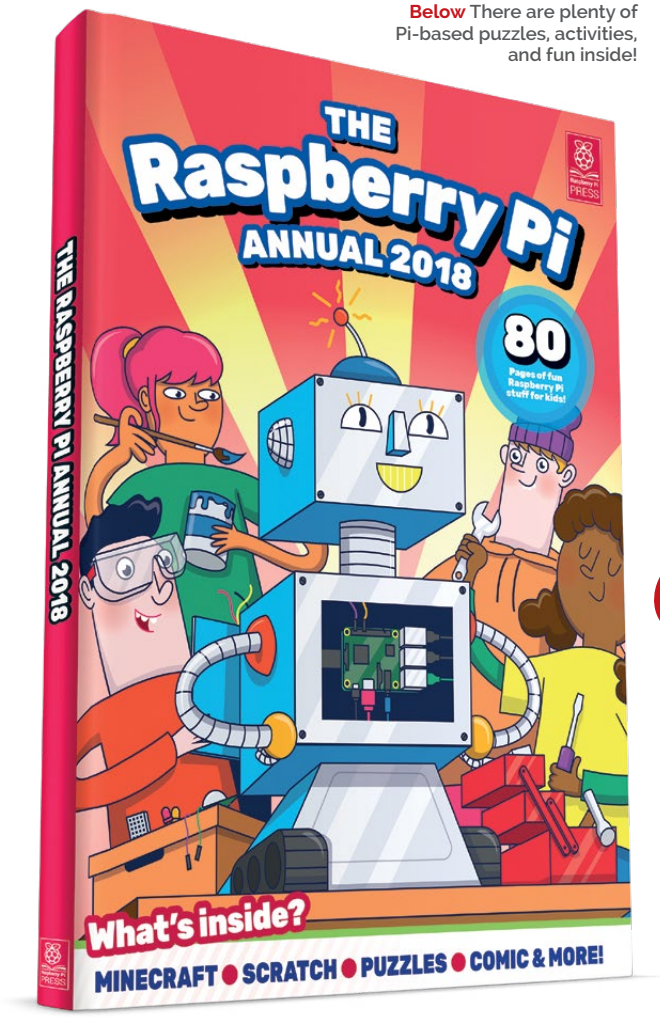

THE Raspberry Pi ANNUAL 2018
80
Pages of fun Raspberry Pi stuff for kids!
What's inside?
MINECRAFT ● SCRATCH ● PUZZLES ● COMIC & MORE!
THE RASPBERRY PI ANNUAL 2018

Below There are plenty of Pi-based puzzles, activities, and fun inside!

FREE RASPBERRY PI ANNUAL

Holiday fun with Raspberry Pi

Holy GPIO! Will the evil Dr Bluescreen succeed with her villainous plan, or will The Founders rescue the children of Earth from a fate worse than Excel? Find out in the first ever Raspberry Pi Annual!

This surprise Christmas present for subscribers of *The MagPi* is "packed with all the great word and picture puzzles you'd expect from any fun-filled annual, but also has a guide on getting started with the Raspberry Pi, as well as lots of fun projects using Scratch, Python, Minecraft, and more," says Russell Barnes, Raspberry Pi Publishing Director.

If you're not yet a subscriber of *The MagPi*, don't panic: you can still bag yourself a copy of the Raspberry Pi Annual by signing up to a 12-month subscription of *The MagPi* before 24 January. You'll also receive the usual subscriber gift of a free Raspberry Pi Zero W (with case and cable). Just head to **magpi.cc/Subs1**.

Or you can buy a copy of the Raspberry Pi Annual for just £7.99 from **store.rpipress.cc**.

TWO PHATS ON ONE PI

Make a pHAT mash-up with RasPiO's latest creation: the FullpHAT

RasP.iO's latest HAT allows you to attach two Zero-sized pHATs to a single Pi. The FullpHAT also exposes all the unused headers and connectors to give you maximum flexibility with your build.

Alex Eames, of RasPi.TV and RasPiO, tells us: "I tend to design and make something that I want to use," explaining that he wanted to crowdfund the FullpHAT to "assess the demand". There have been over 400 orders of the FullpHAT, twice the initial target.

Alex suggests a few uses for the FullpHAT: a RasPiO InsPiRing and a Pimoroni Inky pHAT "go well together ... With an Analog Zero and DAC Zero, you can play music or sounds while reading sensors." As you have all the pins broken out, it's easy to add extra components to your build.

The FullpHAT allows you to attach two pHATs to one Pi – a Pi 3, in this case

As with any HAT stack, you must avoid potential conflicts, "but on Gadgetoid's **pinout.xyz** you can check to see which pins/ports most pHATs use" – great tip, Alex!

The FullpHAT costs only £8, from **magpi.cc/2ku3dfc**.

WEBKIOSK 7 RELEASED

Completes line-up of digital signage and kiosk OSes

Signage and kiosk OS specialist Binary Emotions has released Raspberry WebKiosk 7, completing the migration of its bespoke digital signage and kiosk operating systems to Raspbian Stretch.

According to Binary Emotions' Marco Buratto, "Raspberry WebKiosk is designed for the cheapest possible web kiosks and multi-user web workstations," making the OS ideal for computer terminals in cafes, waiting areas, libraries, and other public spaces.

Marco adds: "Raspberry WebKiosk is a browser-only … hacker-proof operating system [which uses Chromium and] supports printing. System parameters are set by a user-friendly web interface".

Raspberry WebKiosk is the last of Binary Emotions' offerings to be updated to Raspbian Stretch, with the Raspberry Digital Signage and Raspberry Slideshow OSes already updated.

While Raspbian Digital Signage is intended for a permanent, internet-enabled digital sign or display, Raspberry Slideshow is "focused on quick-to-set-up image and video slideshows" running image and videos from a USB drive.

You can download these OSes for free from **binaryemotions.com**.

Use this free, bespoke OS to make a Pi-based internet kiosk

NOW TRENDING

The stories we shared that flew around the world

AIY PROJECTS: VISION KIT

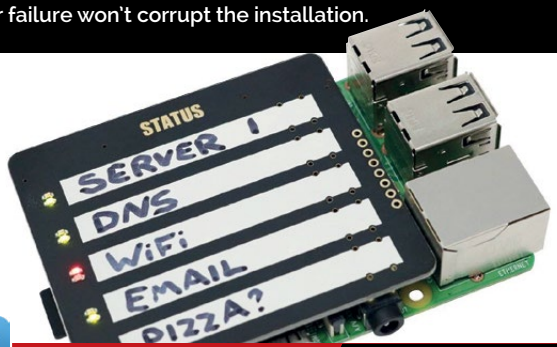
magpi.cc/2Aow5fj

Following the screaming success of Google's AIY Projects Voice Kit comes the new Vision Kit. Its 'VisionBonnet' has a Movidius MA2450 vision processing chip for on-board AI processing.

READ-ONLY RASPBERRY PI

magpi.cc/2n0e3dU

Adafruit's read-only Pi script is ideal for anyone building a 'don't touch again' Pi system. Whether that's for a digital sign or IoT device, the script ensures that power failure won't corrupt the installation.



STATUS BOARD REVIEW

magpi.cc/2j0SSag

Simplicity is sometimes best – why code a web-based push-alert system when you can just use a few LEDs and a Sharpie to find out what's what? The Pi Hut's Status Board offers exactly that.

NEW RASPBERRY PI DESKTOP FOR X86

Updated version for your non-Raspberry Pi PC

The Debian with Raspberry Pi Desktop operating system for x86 computers (that's your common laptop or desktop) has been updated to Debian Stretch.

Below The latest version of Debian with Raspberry Pi Desktop includes a couple of new applications for makers, tinkerers, and teachers

There are also new features that make Raspberry Pi Desktop more useful. PiServer shares the operating system of a central computer with multiple Pis, meaning that each Pi is running exactly the same software. That should be useful for teachers when guiding a lesson, or for CoderDojo and Code Club leaders. See our tutorial on page 38 for information on how to use PiServer.

There's also a new GPIO expander application. The problem with a conventional computer is the lack of GPIO pins, but the GPIO expander enables it to access the pins of a Pi Zero connected via USB. You can use the Zero's GPIO pins in either Python or Scratch 2 once you've installed and configured usbbootgui – see the full instructions at **magpi.cc/2kvGsY5**.

Laptop users now get a battery monitor. "Eben [Upton] runs our desktop on his Mac," says Raspberry Pi UX Engineer Simon Long. "And he was becoming slightly irritated by having to keep rebooting into macOS just to check whether his battery was about to die — so fixing this was a priority."

You can download the latest version of Debian with Raspberry Pi Desktop from **magpi.cc/2joTqNm**.

PITALK AIMS TO MAKE IOT EASY

Modular hardware and software design

PiTalk is an almost 'plug and play' approach to IoT and automation, and can be modified, adapted and added to as you see fit. As long as it hits its Kickstarter target of £1000, that is – see **kck.st/2Bf5EGg**.

Gajender Singh, CEO of SB Components, is keen to explain that while PiTalk is a "multi-appliance communication platform [that can] interface with analogue sensors and, of course, benefits from the flexibility of the Raspberry Pi," its real selling point is that "it's intended for people to use with no or minimum physical remodelling." In other words, no soldering iron required.

As well as not requiring any hardware skills to set up, Gajender tells us, "I didn't want getting it up and running to be the end of the interaction," so PiTalk comes with a ready-to-go software suite.

"The interface is all about making it immediately usable without tying users down to a single use," he confirms.

Above PiTalk is a modular IoT and automation platform, with little setup skill needed – even the screen is optional

THE TAKE-EVERYWHERE TESTING TOOL

BitScope Micro 'no-brainer' for travelling engineers

BitScope's latest scope offers "almost everything you're likely to need" for testing and measurement, according to Bruce Tulloch, BitScope CEO, in a package not much longer than a Pi 3 and less than half as wide.

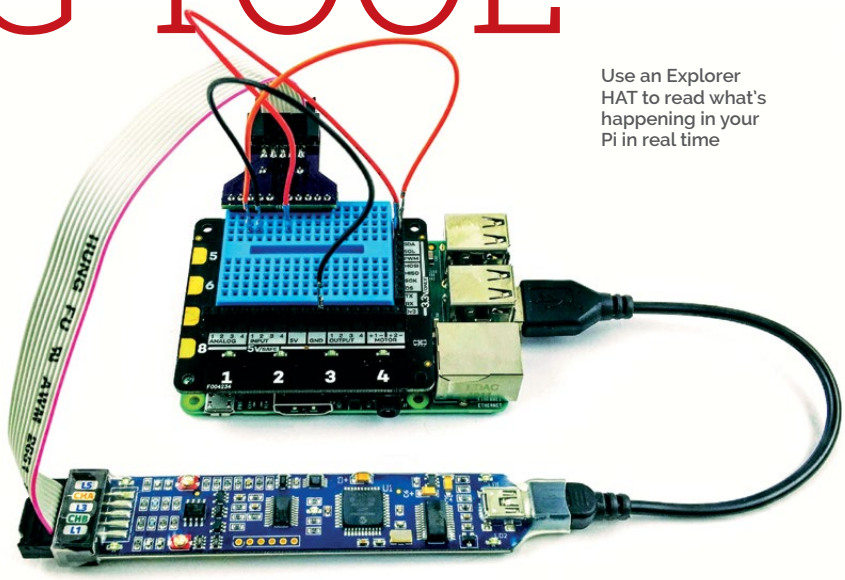
The BitScope Micro (**magpi.cc/2kuJNGS**) "has a pair of analogue channels, six logic channels, and a waveform generator," says Bruce, but it also includes "a high-speed A/D, D/A, compensated inputs, triggers, range and offset controls, and embedded digital signal processing."

The Micro was designed for the Raspberry Pi, and you can even "use BitScope Micro to monitor your project using the same Raspberry Pi," reveals Bruce. In fact, this is how BitScope tests each Micro during production.

"BitScope Micro comes with everything you need to get started," Bruce confirms, but there are other bundles if you need a Hammerhead or Tom Thumb attachment.

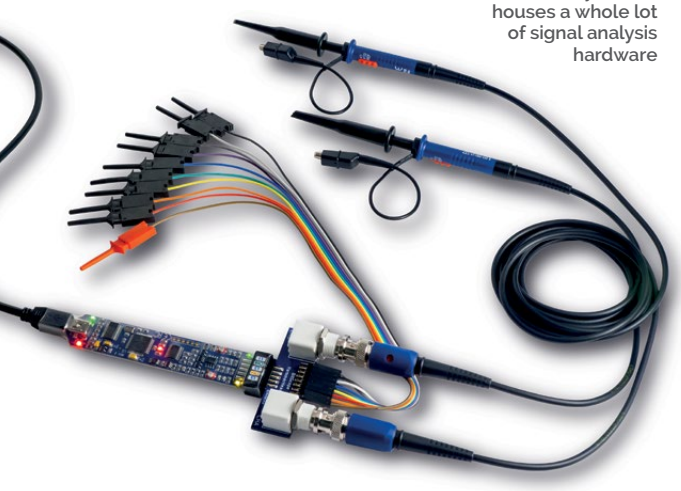
A Pi with a display makes for a "convenient 'stand-alone mixed signal oscilloscope' at a much lower cost," Bruce suggests, while using Pimoroni's Explorer HAT (£18, **magpi.cc/1OAKy46**) allows you to read all the signals that a Pi generates. As Bruce explains, "Without a BitScope Micro, you're more or less 'flying blind' when it comes to seeing and understanding what's actually going on."

The BitScope Micro is available now for $145 (£108), or for $98 (£73) each for orders of ten or more – see **magpi.cc/2kt7wr9**.



Use an Explorer HAT to read what's happening in your Pi in real time

This tiny device houses a whole lot of signal analysis hardware



pi-top

Inspiring inventors and creators to seek the skills of tomorrow and create their future, today.

The modular laptop with sliding keyboard

8HR BATTERY LIFE

14" FULL HD 1080P SCREEN

180° HINGE

CUSTOM PASSIVE COOLING BRIDGE

MODULAR RAIL

pi-top

Colors

Raspberry Pi 3 optional

AWESOME INVENTOR'S KIT INCLUDED

20+ projects to explore

Explore beyond the screen and keyboard by creating with the all-new **pi-top** modular laptop.

Get started with 20+ inventions in the inventor's guide booklet. There are 3 inventor's journeys - Smart Robot, Music Maker and Space Race.

The modular desktop

14" FULL HD 1080P SCREEN

MODULAR RAIL

ADJUSTABLE VIEWING ANGLES

pi-topCEED

Colors

Raspberry Pi 3 optional

pi-topCEED is the plug & play modular desktop. It's the easiest way to use your Raspberry Pi. We've put what you love about our flagship laptop in a slimmer form factor. Join hundreds of code clubs and classrooms using **pi-top**CEED as their solution to Computer Science and STEAM-based learning.

pi-topPROTO

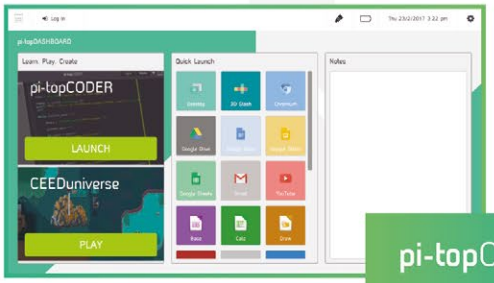
pi-topSPEAKER

pi-topPULSE

Modular **Accessories**

pi-top is an award-winning ecosystem designed to make experimenting, coding and building electronics, simple, affordable and fun. **pi-top**OS is here to guide you through the world of making!

The OCR* endorsed **pi-top**OS (Operating system) platform comes pre-installed on the SD card shipped with every unit. **pi-top**OS software suite lets you - browse the web, - check emails, - create and edit Microsoft Office compatible files. Gain access to dozens of hands-on learning lesson plans with **pi-top**CODER and have fun learning to code with CEED**universe**!

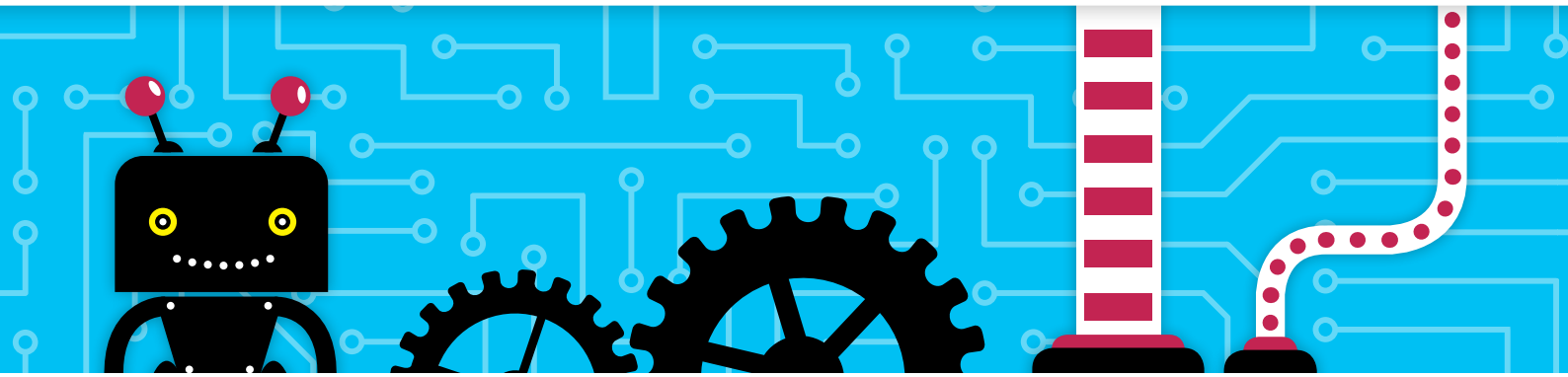


pi-topOS

pi-topCODER has a fully integrated coding environment letting you program hardware, code in Python and learn lots of STEAM skills! Our integrated test framework gives you the ability to assess your own understanding as you learn.

CEED**universe**

Learn programming concepts through our minigames, for example, learn problem decomposition by solving visual programming puzzles.



RASPBERRY PI FOR NEWBIES

Get to know your new Raspberry Pi computer and the community

One of the most common questions we see online is 'I've just got a Raspberry Pi, what should I do with it?'

We've all been there: getting into the latest coolest thing and not being sure where to start. Remember asking your friends what games to get on your first smartphone? If you didn't already keep up with what was hot, you had no idea, and that's the same when you join a new community.

In this article we'll show you how to get started with your Raspberry Pi hardware, as well as how to join the global Raspberry Pi community and become a maker.

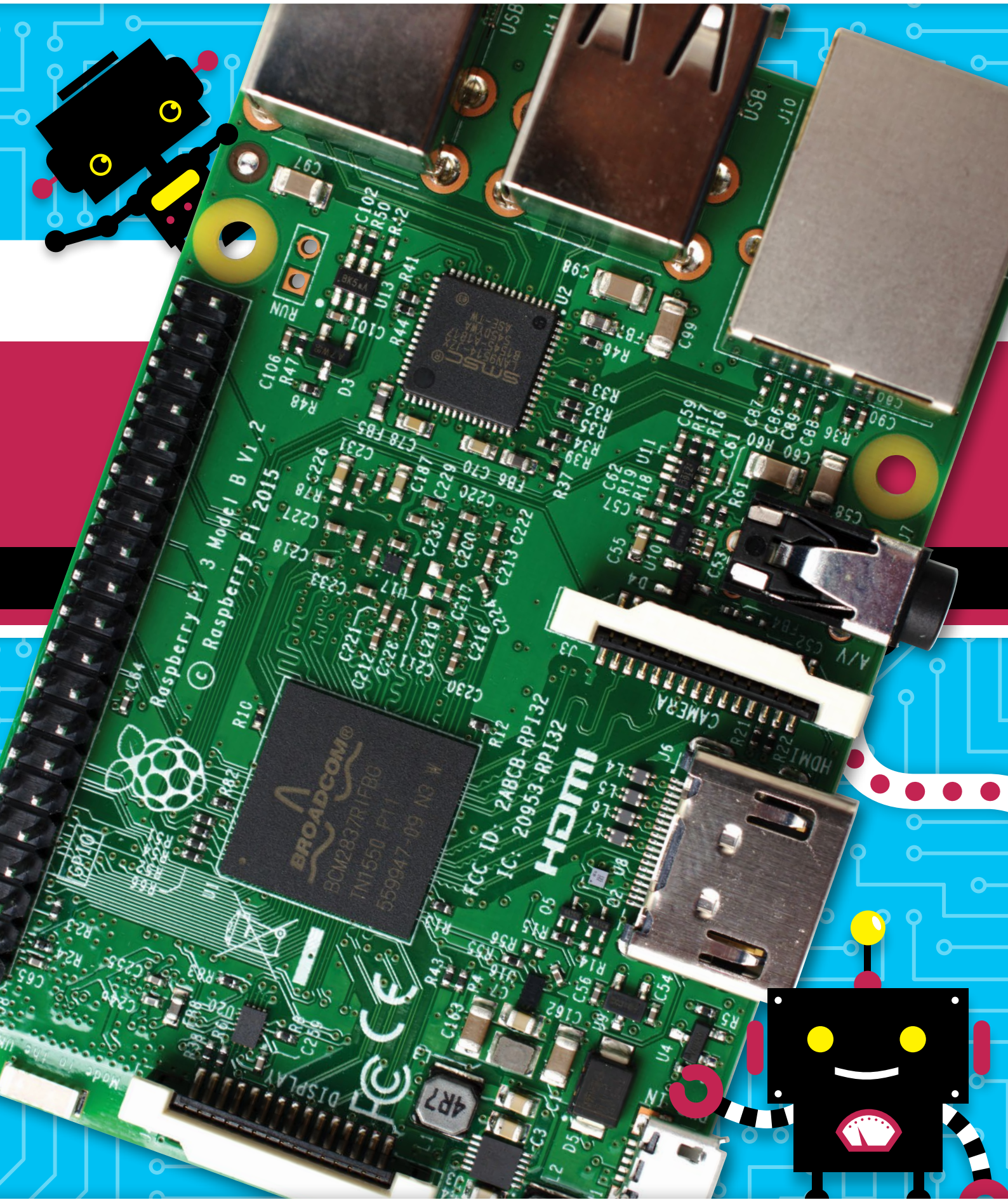
Welcome to the world of Raspberry Pi.

ARM: The type of processor the Raspberry Pi uses. It's typically used in small devices such as smartphones

Desktop/Desktop environment: The graphical interface you control with a mouse and keyboard

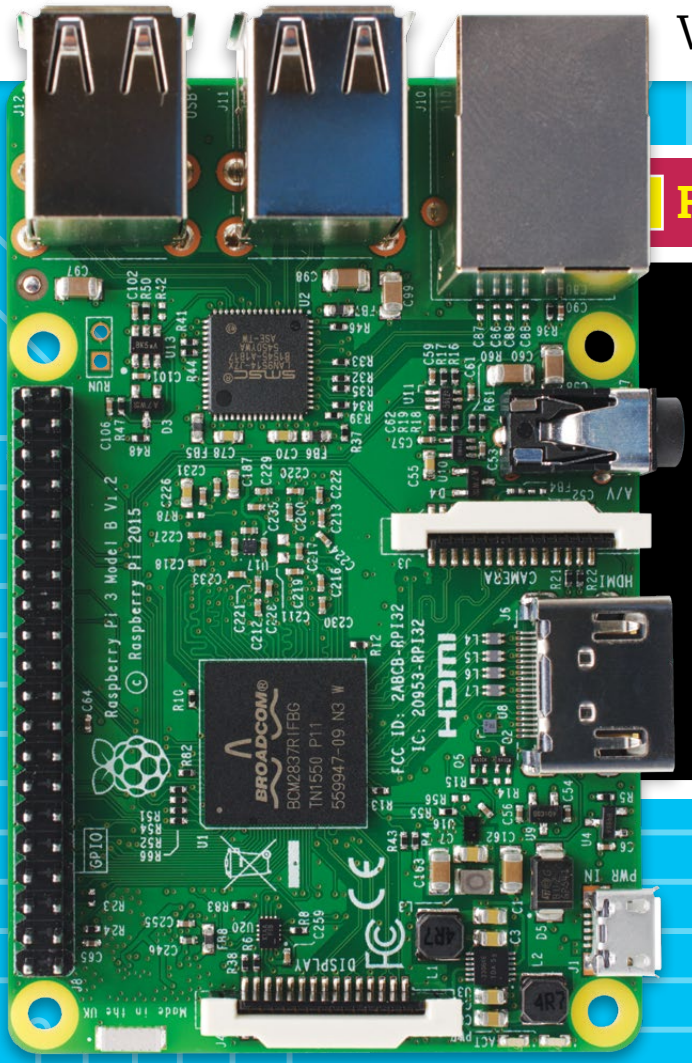
GPIO: General-purpose input/output, these are the pins that line the side of a Raspberry Pi and allow you to connect electronic components to it

Terminal: A program that lets you type in commands. It's how computers worked before a desktop environment


Raspberry Pi 3 Model B V1.2
© Raspberry Pi 2015
BROADCOM
BCM2837RIFBG
FCC ID: 2ABCB-RPI32
IC: 20953-RPI32
HDMI
CAMERA
DISPLAY
USB
RUN

GET TO KNOW YOUR PI

What actually is the Raspberry Pi?



RASPBERRY PI 3

Processor: 1.2GHz quad-core ARM processor

Memory: 1GB

Networking: Ethernet, wireless

Connectivity: HDMI out, analogue audio/video out (3.5mm headphone hack), Bluetooth 4.1, 4× USB 2.0 in, micro USB power, 40-pin GPIO, Camera Module port (CSI), Display Module port (DSI), microSD card slot

Dimensions: 86 × 56 × 17mm

Weight: 45g

PI ZERO W

Processor: 1GHz single-core ARM processor

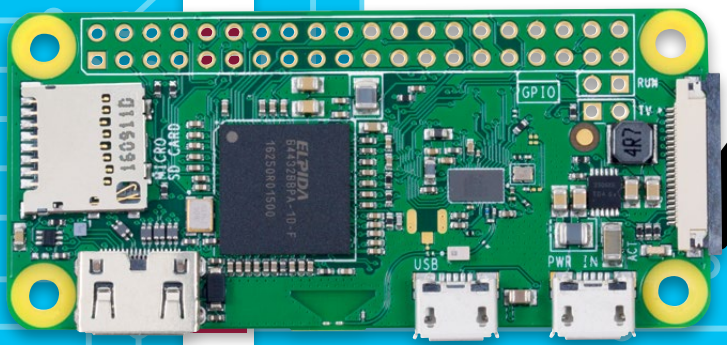
Memory: 512MB

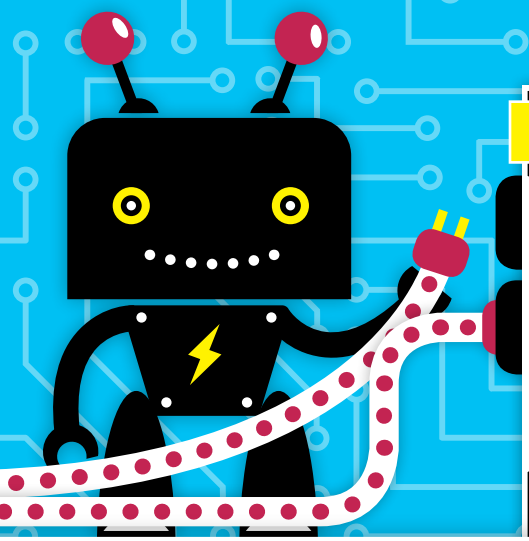
Networking: Wireless

Connectivity: Mini HDMI out, Bluetooth 4.1, micro USB in, micro USB power, 40-pin GPIO, Camera Module port (CSI), microSD card slot

Dimensions: 65 × 30 × 5mm

Weight: 9g





WHAT CAN YOUR RASPBERRY PI DO?

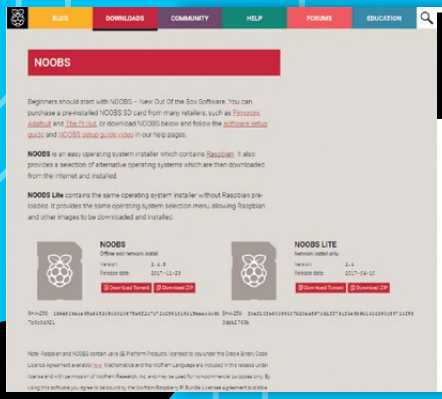
The Raspberry Pi is a full computer. It has a processor, graphics processor, and memory, just like a normal computer or laptop – it's just a lot smaller.

The Raspberry Pi can be used in any situation a computer could be used. This can be as simple as being used as your desktop computer, or plugged into a special laptop shell. Other people use them as mini servers in their house, as media computers for their TV, or as tiny computers to power their fun projects. It could be the brains of a robot, control a vegetable garden, or even just blink a light.

The possibilities with Raspberry Pi are limited only by your imagination.

SET UP YOUR RASPBERRY PI

First time using a Raspberry Pi? Here's how to get it ready

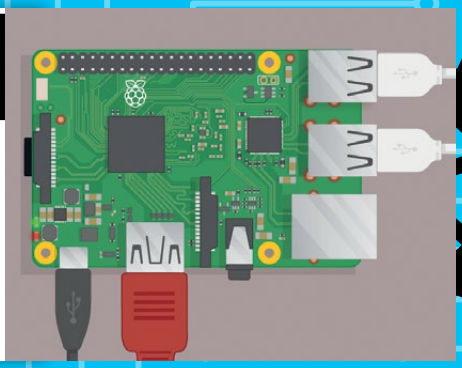


>STEP 01 SET UP YOUR MICROSD CARD

The first thing you need to do is make sure your microSD card has an operating system on it so that the Raspberry Pi can run. For newcomers, NOOBS is the recommended way of installing Raspbian, the Raspberry Pi operating system. Download it from **magpi.cc/2bnf5XF** and then unzip the files directly onto a freshly formatted microSD card.

>STEP 02 HOOK IT UP

Like any computer, you need to make sure everything is plugged in properly. Connect the monitor with the HDMI cable to the HDMI port on the Pi, firmly push the microSD card into the slot under the board, plug in your mouse and keyboard, and then finally insert the power so it turns on.



>STEP 03 INSTALL RASPBIAN

NOOBS will give you the option to use one of many operating systems on your Raspberry Pi. Select 'Raspbian with Raspberry Pi Desktop' and it will boot into it. From here you can set up your wireless internet and any user preferences. It's also a good idea to update the files by opening the Terminal (via the little black box in the top bar) and typing the command:

```
sudo apt-get install update
```

...and then press **RETURN**, followed by the command:

```
sudo apt-get install upgrade
```

ESSENTIAL EQUIPMENT

MICRO SD CARD

MONITOR

KEYBOARD

MOUSE

HDMI CABLE

POWER SUPPLY (2.5 A)

CASE

OFFICIAL WAYS TO LEARN ABOUT RASPBERRY PI

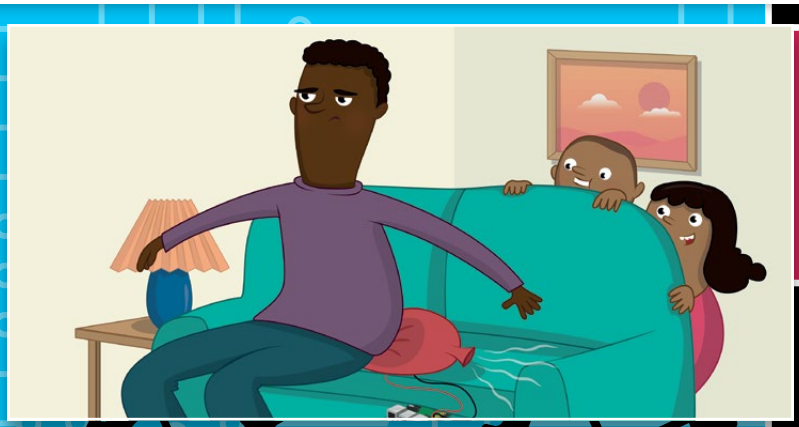
Free resources from the Raspberry Pi Foundation to help you on your way

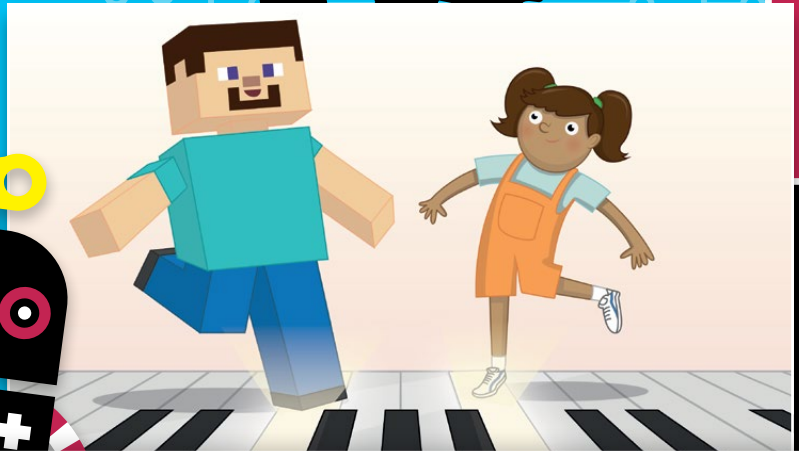
When most people think about the Raspberry Pi, they think of the computer. What a lot of people don't know is that the Raspberry Pi Foundation is a charity that also provides free resources for people wanting to learn about computing and making. This doesn't just apply to making stuff with the Raspberry Pi either.

RASPBERRY PI RESOURCES

raspberrypi.org/resources

The Raspberry Pi Foundation has a rich history of providing free resources for both makers and teachers alike, including offering free teacher training courses with Picademy (**magpi.cc/2Bakf96**). These range from simple programming lessons to full-on physical projects you can build in your own home. Here are some of our favourites.





WHOOPI CUSHION

magpi.cc/2AgN6IW

This is an excellent project that melds physical making and computer programming. Also, it's an electronic whoopee cushion. This extremely fun project is pretty simple to make with just some foil, paper plates, and other bits you should be able to find around the house.

SCRATCH OLYMPICS WEIGHTLIFTER

magpi.cc/2B9f0f1

There are plenty of Raspberry Pi resources that make use of Scratch, a beginner's programming language that makes use of blocks to create code. This weightlifter game uses fun retro sprites and a classic game mechanic that you learn to make yourself. You can then challenge your friends on it!

GET STARTED WITH WEARABLES

magpi.cc/2B9066l

The Raspberry Pi's diminutive size means it's great for projects where space is at a premium. Wearables are a great example of this, and this excellent project teaches you how to upgrade your clothes with some Raspberry Pi magic and a few excellent programmable lights.

BIG MINECRAFT PIANO

magpi.cc/2B9KGvY

There's a special version of Minecraft on Raspberry Pi that you can modify by programming in Python. This particular project shows you how to recreate the big piano from the movie *Big* in Minecraft, allowing Steve to jump around and make his own music.

CODE CLUB RESOURCES

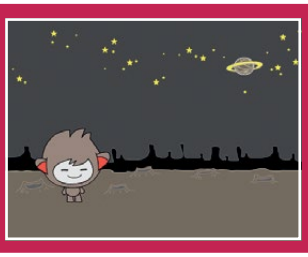
Code Club is a network of after-school and extracurricular computing clubs that provides free resources for kids aged 9–13 to learn how to code using Scratch and Python. There are thousands of clubs around the globe, so check to see if there's one in your local area. You can even start a Code Club if you want, and there's more info for that on the site. Here are some of our favourite projects.

codeclub.org.uk

CHATBOT

magpi.cc/2AgAUb4

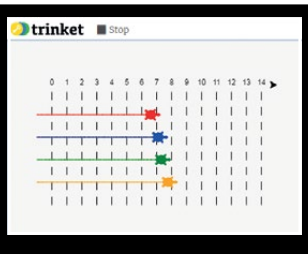
Want to talk to your computer? This fun Scratch project lets you create a 'chatbot', a program that tries to simulate the experience of talking to someone. Asking it specific questions will elicit specific responses.



TURTLE RACE

magpi.cc/2kLBki6

This simple Python game has you racing four turtles against each other. The outcome is random each time, so you'll be cheering for your chosen turtle throughout the entire race. This project also teaches some animation tricks with simple graphics.



LIVE DJ

magpi.cc/2kwaOK9

Sonic Pi is a cool program that lets you write music using code! There's a series of Sonic Pi tutorials from Code Club which teach you the basics of creating your 'loop' for music before finishing off by teaching you how to put it all together in a live show.

THE MAGPI RESOURCES

Oh hey, that's us! We're the official Raspberry Pi magazine, made for the community. Not only is this our 65th excellent issue, we also have a selection of pocket books on single subjects in our Essentials range, as well as our yearly Project Books. If you can't afford or find older issues, every issue of *The MagPi* is available as a free PDF online from our website. Here are some of our favourite releases for beginners – so far!

magpi.cc

ISSUE 50: 50 GREATEST RASPBERRY PI PROJECTS

magpi.cc/2dcswel

Want to be inspired by all the amazing stuff people have made in the community? We count down the 50 best projects as voted for by the community. We could easily do 50 more amazing projects as well – there are so many talented people in the community!

ISSUE 64: ELECTRONICS STARTER GUIDE

magpi.cc/2AqrV6q

Our previous issue! Here we show you how to read electronic circuits, and how to construct them so you can make your own amazing projects. Raspberry Pi makes it relatively easy, but you still need a stepping-off point.

SIMPLE ELECTRONICS WITH GPIO ZERO

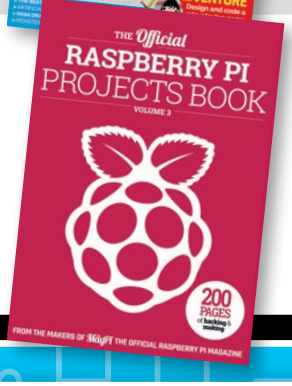
magpi.cc/2bA3ZP7

Want to learn how to program physical objects on your Pi? The GPIO Zero library for programming language Python makes this very easy, and this book takes you from the basics all the way to controlling a robot with it.

THE OFFICIAL RASPBERRY PI PROJECTS BOOK VOLUME 3

magpi.cc/2Aige2w

Our Projects Books are crammed full of projects and guides that will both inspire you and help you make some incredible things. Our latest version has 200 pages of Pi articles and the cover is very swanky, if we do say so ourselves.



JOINING THE COMMUNITY

The Raspberry Pi community is huge and welcoming to everyone

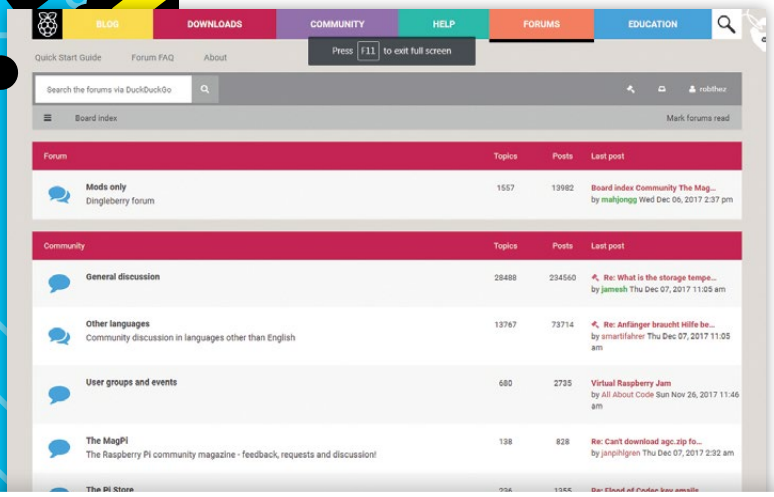
We've talked about how the Raspberry Pi is both a computer and a charity, but it's also a huge community of like-minded makers and coders. Don't be intimidated, though! The community is very welcome to newcomers, as the Raspberry Pi is all about getting people excited to use computers. Here's how you can dip your toes into the community at large.

THE OFFICIAL FORUMS

raspberrypi.org/forums

The official Raspberry Pi forums are a thing of wonder. Hundreds of people come together to help people with their projects and problems – from simple things to incredibly advanced Linux tweaking. If you ever have an issue with the Raspberry Pi or Raspbian, head to the forums and use the search function to see if anyone else has ever had a similar problem and if not, start a new thread.

There are sub-forums dedicated to many specific parts of Raspberry Pi, from beginner's guides and troubleshooting to education chat and info on programming in specific languages.

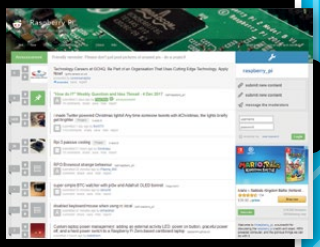


OTHER FORUMS

Some Raspberry Pi help and discussion can be found outside the official community forums, sometimes dedicated to more specific software or hardware. Here are some good places to take a look for more Raspberry Pi.

RASPBERRY PI SUBREDDIT

magpi.cc/2AhI042

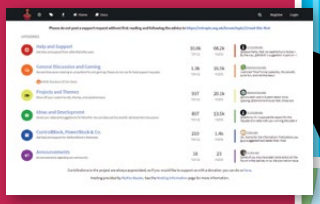


The Raspberry Pi subreddit is a great place to see some of the coolest projects from the community get highlighted, as well as get news from the community itself about products and updates! They'll even answer some Pi-related queries, although you should check out the official forums for that first.

It's also a great place to show off your project and get feedback for it from the community at large – it's always fun to have a little following, after all!

RETROPIE FORUMS

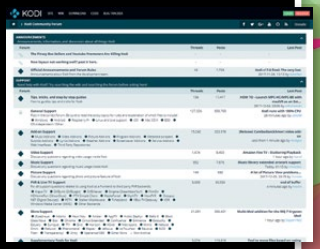
magpi.cc/2B9laHb



A lot of people like to use the Raspberry Pi to play retro games on it, and RetroPie is one of the premier bits of software for the Raspberry Pi that lets you do this. The forums cover almost everything about the project, including basic help and support, ideas for modding and improving your RetroPie, and even a bit of game discussion as well!

KODI FORUMS

forum.kodi.tv



Equally as popular as retro gaming, the Pi is great as a media PC hooked up to your living room TV and most home-theatre PC software solutions will use Kodi for this. While you may be better off looking at the documentation for your particular software, if that doesn't help then you can always check out the Kodi forum. It's a big and busy forum, though, so remember to make good use of the search function!

CODE HELP

It's probably no surprise to hear that there are a lot of people in the world who code. Whether they're professional coders for big companies or teens playing with Python, they all have one thing in common: sometimes they might need a little bit of help. There are a couple of great places to head to when you find yourself up against a proverbial brick wall.

GOOGLE

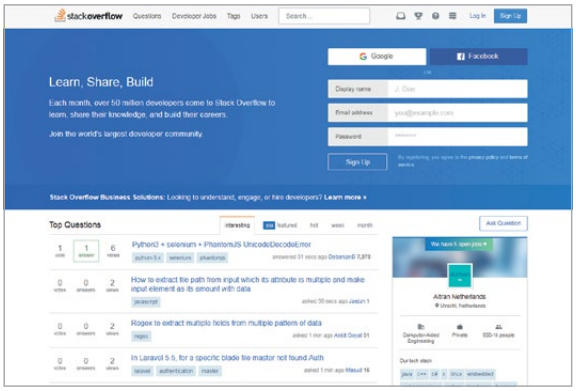
google.com

We're not being patronising here – a good Google search will genuinely help you out with many code issues. There's nothing new under the sun as they say, and there's usually someone who has had the exact same issue as you, or you might trip over the wording for what you want to do in a very helpful bit of official documentation. Always give any issue a quick Google and you may be surprised at how easy you can find an answer, and how simple the solution may be.

STACK OVERFLOW

stackoverflow.com

This website is one of the best places to ask about coding problems as not only is it incredibly popular, rewards are given to people who help out with an answer. We've seen people ask questions on a huge number of topics at varying skill levels, such as how to correctly call an item from a Python list or use complex database commands for a website. There's also a robust search feature included, and Google will generally point you towards pages on Stack Overflow if you've looked there for answers first.



SOCIAL MEDIA

Here are some great social media accounts that you should follow

TWITTER

@Raspberry_Pi
The official Raspberry Pi Twitter account

@TheMagP1
Our official Twitter account

@pimoroni
Maker of fun Pi projects and add-ons

@FormulaPi_
Raspberry Pi-powered racing robots

FACEBOOK

raspberrypi
The official Raspberry Pi Facebook account

MagPiMagazine
Our official Facebook page

RpiSpy
Raspberry Pi Spy is a great way to keep up on Pi news and see awesome tutorials

codeclubuk
The official Code Club UK Facebook account, keeping you up-to-date on all the cool things they do

PROJECTS FROM THE COMMUNITY

Want to be inspired? Here are some amazing projects that we've seen from the community

Every day we keep an eye on Twitter and Reddit to see what amazing stuff people are coming up with to do with their Raspberry Pis. Here's just a taster of what we see online and what you can see in the magazine.

AIY PROJECTS

MARTIN MANDER'S INTERCOM PROJECT IS RETRO AND LOVELY

magpi.cc/2vPQK6E

An amazing project that uses the AIY Projects Voice Kit from issue 57 to hack an old-school intercom to become a digital voice assistant. It's an ingenious bit of repurposing, and we always love seeing what Martin Mander is going to upcycle next. For some reason, though, everyone else has been having the same idea and we saw loads of toy phones and intercoms and other voice-powered products upgraded with an AIY Voice Kit. Here are a couple of our favourites...

OPERATOR!

magpi.cc/2vN4rEo

More retro upcycling with this old-school phone upgraded with an AIY Voice Kit. Just dial 0 and you can talk to the assistant to get answers to your everyday queries. We have visions of someone just picking it up and putting it under their chin to ask for ounce-to-gram conversions while they mix some batter, Nineties style.

Arden Albert
@ArdenAlbert
Follow
Got our retro home assistant running with @Raspberry_Pi and #GoogleAssistant . Now we can dial '0' for the operator (Google)! #AIYProjects

KIDS SMARTPHONE

magpi.cc/2vMuSty

This one is a little mean but honestly, we laughed. The Fisher-Price toy phone is a true classic and we love the idea of it getting a very hefty upgrade with AIY, complete with massive glowing button in the centre. Would it be creepy if you had it sing while the eyes moved? Very probably.

Simon Jackson
Follow
My kids have now got a #Google #Assistant @TheMagP1 #AYI. My six year old said he wanted a #Smartphone. Ask and ye shall get!!

WEEKEND PROJECTS

OUT RUN TOMY TOY

magpi.cc/2xckwUo

While we have seen many console or arcade hacks over the past few years, this inventive hack of one of those sports car dashboard kids toys wowed us when we saw it. It doesn't hurt that it's themed around Out Run, one of the best arcade series of all time.

FRED-209

magpi.cc/2BjtDak

A custom Nerf-firing robo-tank that gives you only 20 seconds to comply. We got a bit of a preview of this last month and we've been excited to see the final product. Follow the link to learn more and see it in action!

David Pride
@davejavupride
Following
@Raspberry_Pi @TheMagP1 Meet FRED-209. A #RaspberryPi powered, #3DPrinted Nerf Tank! Details and video here: bit.ly/2hc9Y03

HALLOWEEN PROJECTS

POSSESSED PORTRAIT

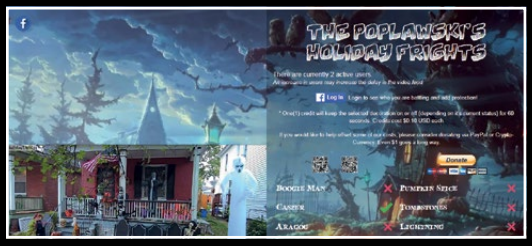
magpi.cc/2yMfQrI

The picture for this project doesn't really do it justice, so take a quick look at the video: **magpi.cc/2yMgAgu**. Needless to say, it's a very effective and scary project that uses a little illusion and a motion sensor to make you think the painting is moving. And attacking.

HAUNTED JACK-IN-THE-BOX

magpi.cc/2yMcogZ

This automated jack-in-the-box uses a camera to detect if someone is around. If you turn up in front of it, surprise! Pop goes the weasel and also about three years off your life. Put it in an inconspicuous part of your house to scare the bejeesus out of friends and children.



THE POPLAWSKIS' HOLIDAY FRIGHTS

magpi.cc/2yMfIse

The theme has since been changed to Christmas holiday lights, but the original setup allowed you to control Halloween decorations on the Poplawkis' lawn. There's a camera recording the whole thing, and you can control various decorations – with the option to keep your selection active for one minute by spending a credit (costing 10 cents).

COMMUNITY EVENTS

Meet Raspberry Pi users in real life and see talks by computing boffins that might help you

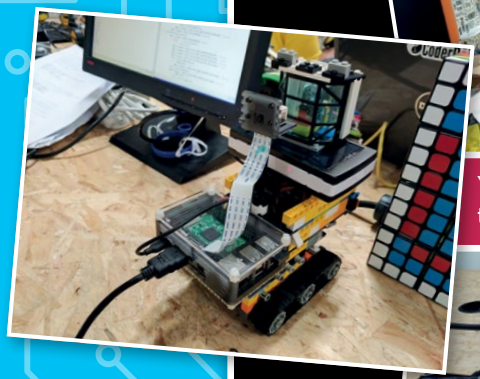
The Raspberry Pi community online is so big that it regularly leaks into the real world, usually through the power of a Raspberry Jam. However, the Pi makes itself into many other events that involve technology, such as Maker Faires.

CODERDOJOS

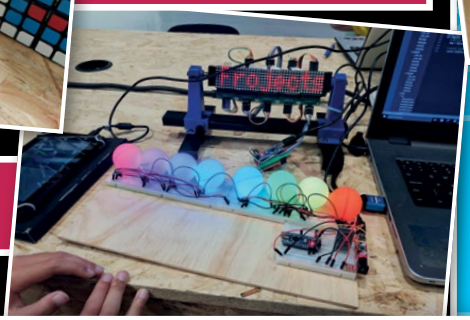
CoderDojo is part of the Raspberry Pi Foundation and, much like Code Club, provides free resources for people wanting to create programming clubs for kids. There are also CoderDojo events such as the Coolest Projects showcase, allowing young people to show off the awesome stuff they've been making.

coderdojo.com

Pi-monitored bees make them a bit safer to keep



You can find robots galore at the Coolest Projects showcase



Glowing ping-pong balls are a favourite for LED projects

RASPBERRY JAMS

A Raspberry Jam can be a lot of things, but usually it's a social event people can attend to learn about the Raspberry Pi. Typically you'll see people showing off their projects, as well as stalls where you can buy Raspberry Pi add-ons and electronics kits.

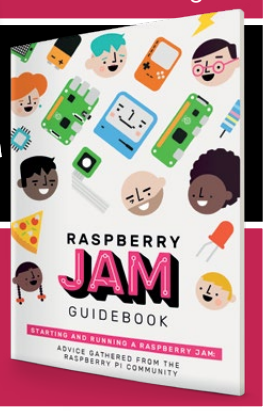
These Jams are hosted by community members; in fact, anyone can host a Jam if they wish! Head over to the info page to find out more on Raspberry Jams, including an events calendar so you can try to attend one!

rpf.io/jam

The Raspberry Pi birthday parties are huge, weekend-long Raspberry Jams!

The yearly robot challenge Pi Wars spun off from the popular CamJam

Be sure to check out the **#raspberryjam** hashtag on Twitter to see what awesome things people are showing off



GET INVOLVED

Get all the info you need to set up your own Raspberry Jam: **magpi.cc/2q9DHfQ**

RASPBERRY PI RETAILERS

Want to buy more Pi goodies? Take a look at these places...

PIMORONI

shop.pimoroni.com

Purveyor of Raspberry Pi goods and general maker ware, Pimoroni is one of our favourite places for fun and beginner-level projects, while also offering plenty of components for almost any project you can think of making.

ADAFRUIT

adafruit.com

Adafruit not only creates incredible electronics for makers, but also posts amazing tutorials that make use of some of its electronics. There's plenty of Pi-compatible stuff and it's perfect for getting Pi paraphernalia if you live in the US.

MODMYPI

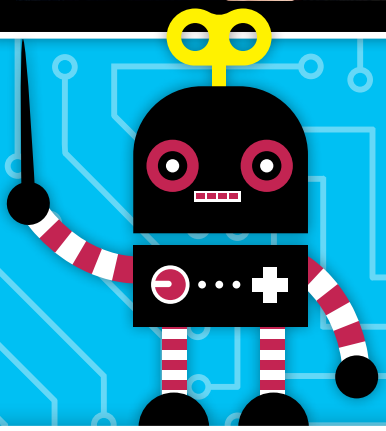
modmypi.com

While it does carry a lot of Raspberry Pi-specific hardware and add-ons, we love how much maker gear you can also get at ModMyPi, including obscure components you might have trouble finding elsewhere.

THE PI HUT

thepihut.com

The Pi Hut sells a lot of Pi add-ons and gear, along with robot parts from the excellent PiBorg, as well as a host of simple kits like the cute 3D Xmas Tree. It also has a robust maker store with plenty of extra parts you'll need for many projects.



PI SUPPLY

pi-supply.com

A great online store for everything Raspberry Pi, Pi Supply usually has some very interesting Pi add-ons, and they accompany projects as well, including the Flick 3D gesture boards and the PiJuice mobile power HAT.

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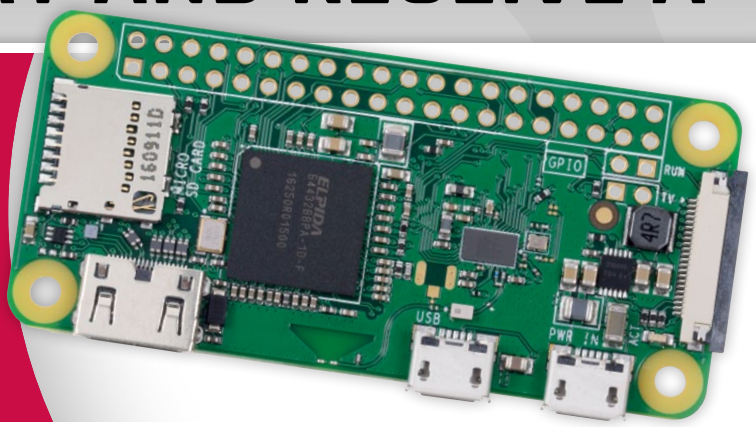
FREE PI ZERO W



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The official Raspberry Pi magazine
Issue 65 January 2018
APHEX TWIN MIDIMUTANT
Megastar talks to us about new AI music tool
RASPBERRY PI FOR NEWBIES
Set up and start using your Raspberry Pi
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MAKE GAMES IN C++
Professional video game development
PI-TOP LAPTOP REVIEWED!
The pro laptop with Pi inside
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Build a ringing bell tower
VISION
Also inside:
BUILDING A SMART BABY MONITOR
EASY TRAFFIC LIGHTS WITH PI TRAFFIC HAT
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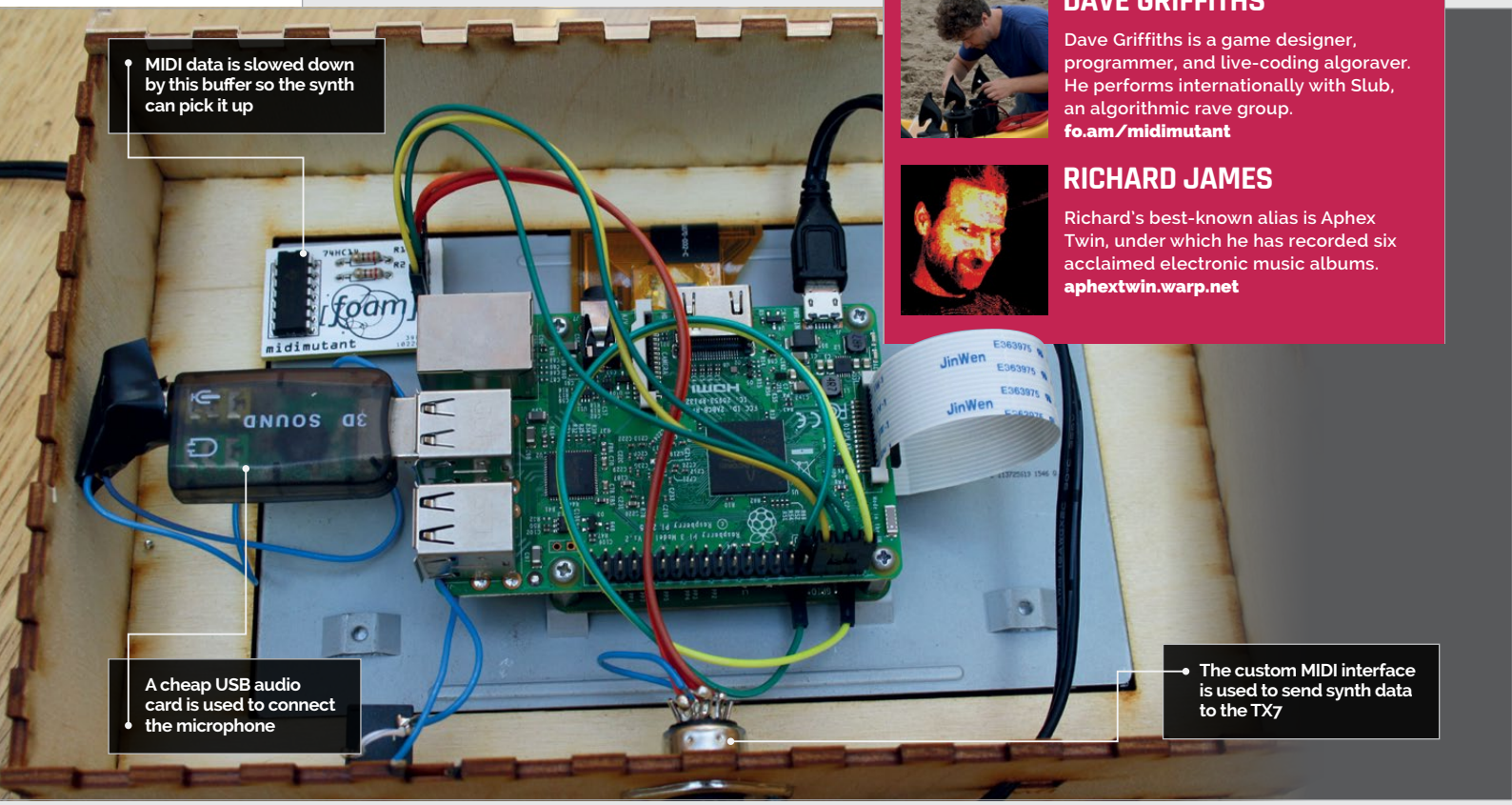

MIDI data is slowed down by this buffer so the synth can pick it up
A cheap USB audio card is used to connect the microphone
The custom MIDI interface is used to send synth data to the TX7
midimutant
JinWen

DAVE GRIFFITHS

Dave Griffiths is a game designer, programmer, and live-coding algoraver. He performs internationally with Slub, an algorithmic rave group.
fo.am/midimutant

RICHARD JAMES

Richard's best-known alias is Aphex Twin, under which he has recorded six acclaimed electronic music albums.
aphextwin.warp.net

APHEX TWIN MIDIMUTANT

Quick Facts

- Making a good patch manually can take days
- Midimutant can make thousands of patches per day...
- ...But only about half of them are useful
- Dave coded Midimutant in C++
- He now has 3792 saved Midimutant DX7 patches

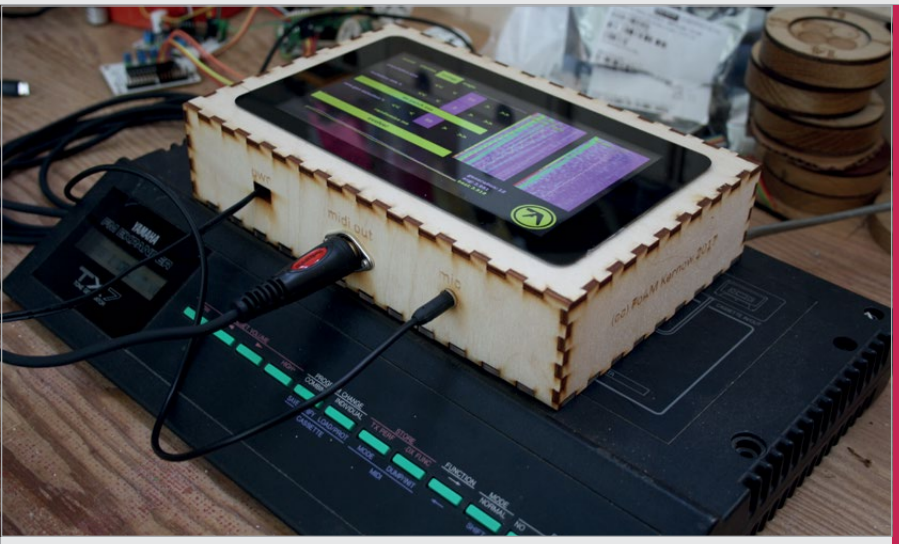
Somewhere in Cornwall, there's a synthesizer that boinks endless strange sounds as they slowly evolve towards a new synth patch. **Sean McManus** investigates

If you're a fan of '80s pop, you'll have heard the Yamaha DX7. It's one of the best-selling synthesizers, and its built-in sounds can transport you to the era of big hair and neon leggings. One reason it is evocative is that so many artists used those preset sounds, to the point of them becoming a cliché. The synth is based on frequency modulation (FM), and it could take a few days to create a good patch (or sound). Many chart-toppers took the easy way out.

"I'm nuts about FM synthesis," says Richard James, who creates electronic music as Aphex Twin. "The first proper synth I got was a DX100 and I've always thought there's got to be a more interesting way to program the damn things than laboriously going through all the hundreds of parameters. Even though I quite like doing that anyhow, hehe."

A conversation with his friend Dave Griffiths led to Dave building Midimutant, a Raspberry Pi-based device that programs the synth for you. "This is something you want to leave running for hours," says Dave. "The Raspberry Pi is essential because you can make a stable setup that isn't going to start updating itself and reboot."

The idea came from a lost feature on the Kyma synth, based on the work of Andrew Horner, which enables sounds to evolve. Midimutant uses a similar approach: you give it a sound, and it aims to recreate it on the Yamaha TX7, a version of the DX7 without a keyboard. "There's nothing especially great about a TX7 apart from I love all forms of FM and that is a really small unit, so it's a lot easier to handle than



a DX7 or other FM devices I've got lying about," says Richard.

Dave adds: "The DX7 is the 'classic' FM synth. If it works on that, it would work on anything."

Above Midimutant sits on top of the Yamaha TX7 synth. The Raspberry Pi Touch Display is used for control

Random scoring

At the start, a population of random sounds is created. Each one is compared to the source sound using Mel-frequency cepstral coefficients (MFCC), a way of comparing sounds that comes from recent work on speech recognition.

it usually (although not always) converges on something good," says Dave. The most interesting sounds emerge from trying to match beats and voices.

One fascinating aspect of the project is that Midimutant doesn't need to understand how the synth functions. It just needs to know how to format the (initially random) data so the synth can use it, and it uses the sound the synth produces to score the results.

> "The DX7 is the 'classic' FM synth. If it works on that, it would work on anything"

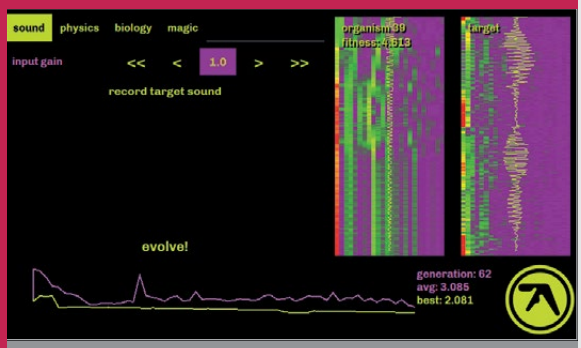
Each of the random sounds is scored and ranked for its similarity to the source. The program gets rid of the lowest scoring half, and creates a new population by copying with errors (mutation) and crossbreeding (mixing together) the top half. "Repeat this process tens or hundreds of times and

The biggest challenge? "Listening to endless bonkers sounds for days on end, changing parameters slightly and waiting ages to see if there was an improvement," says Dave. "Actually, that was quite fun..."

The Yamaha DX7 is an iconic synth, but Midimutant should work with other FM synths too

Image credit: Flickr user deepsonic (CC BY 2.0)

MAKING MIDI SOUNDS WITH MUTATION



>STEP-01

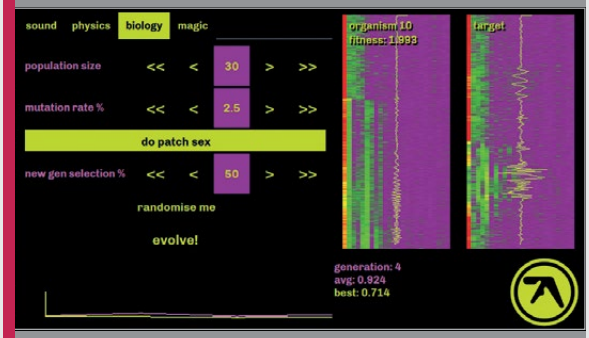
Record your sound

Use the USB microphone to record the source sound you want Midimutant to try to match. Short sounds will evolve faster.

>STEP-02

Run the algorithm

Midimutant creates a random set of synth patches. It sends the data to the synth using MIDI. The synth plays the sound, and Midimutant 'listens' with the microphone.



>STEP-03

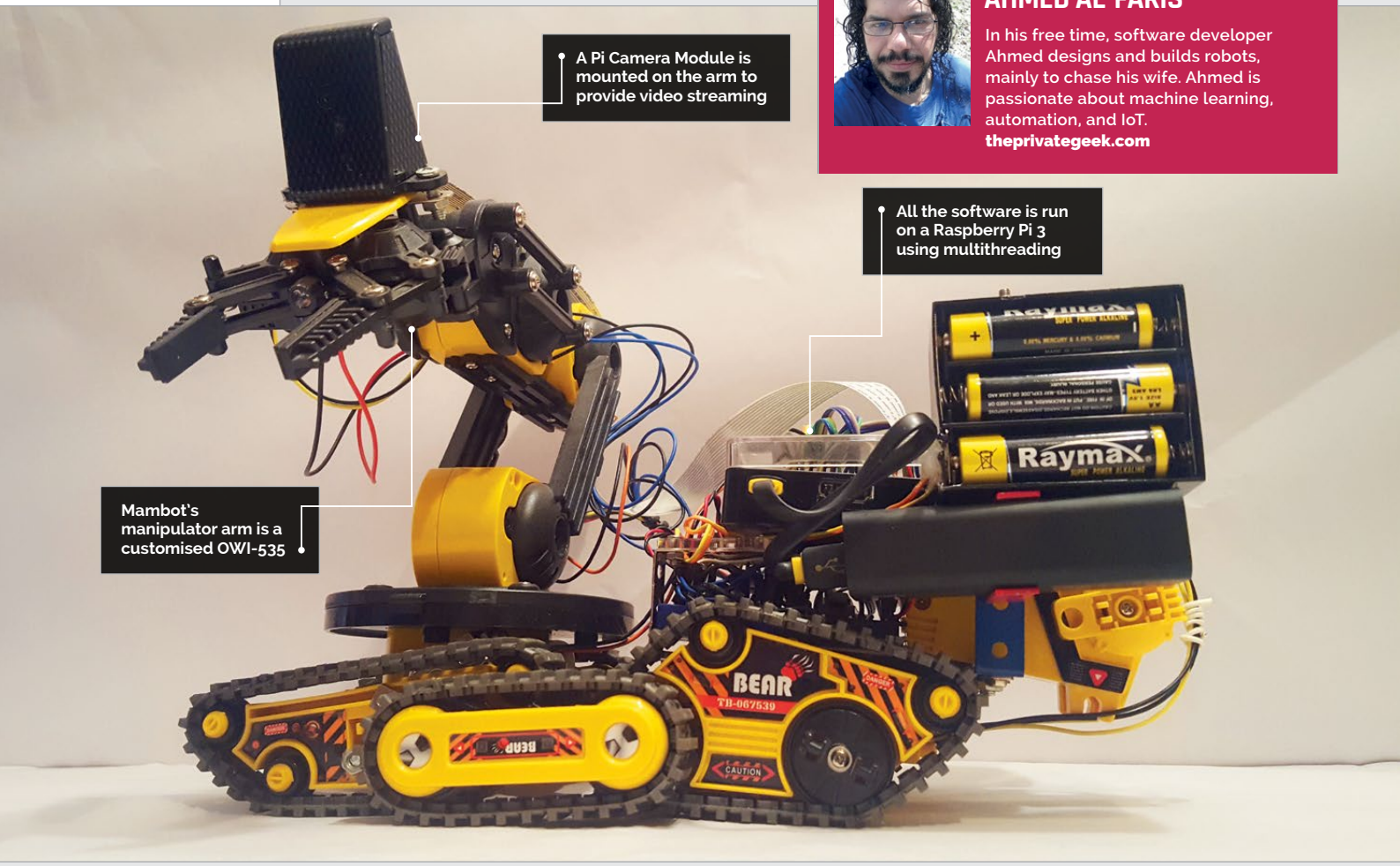
Do patch sex!

The sounds are compared with your original. The best ones are evolved with random mutations. Use the 'patch sex' option to combine sounds, too. For best results, leave it running overnight.

AHMED AL-FARIS

In his free time, software developer Ahmed designs and builds robots, mainly to chase his wife. Ahmed is passionate about machine learning, automation, and IoT.

theprivategeek.com


A Pi Camera Module is mounted on the arm to provide video streaming
All the software is run on a Raspberry Pi 3 using multithreading
Mambot's manipulator arm is a customised OWI-535
Raymax
BEAR
TB-007539
CAUTION

MAMBOT

Is there anything **Ahmed Al-Faris**'s remarkably versatile robot can't do?

Quick Facts

- Mambot has seven degrees of freedom
- The camera streams video to a local web address
- Six AAA batteries power the motors
- Mambot originally had a wagging tail
- Shape and colour recognition are planned

We get to see a lot of Pi-powered robots, but rarely (if ever) one crammed with quite so many features as Mambot (**youtu.be/AtQqE1M9Ff4**). The creation of software developer Ahmed Al-Faris, it features a manipulator arm, five control methods (including autonomous), video streaming, Alexa voice interaction, obstacle avoidance system, and the ability to read text. Not only that, it is even integrated with the eAccounting ERP system at Ahmed's employer, Visma Software International, enabling it to scan and handle orders.

Above Ahmed first experimented with mounting the arm on a two-wheeled chassis, before opting to customise an OWI All Terrain Robot kit

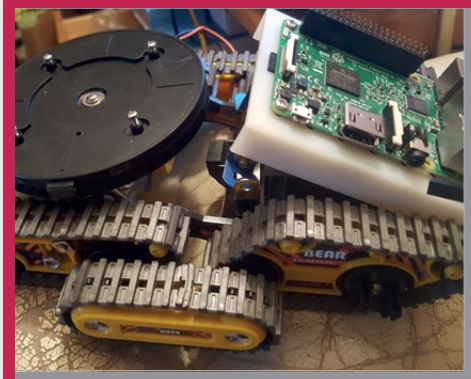
It has certainly come a long way since Ahmed's original aim: "At the beginning, I just wanted to turn two wheels using the Pi." He reveals that the Mambot hardware is constructed primarily from the OWI-535 robot arm and OWI All Terrain Robot kit. "Both have been disassembled, reconfigured, and customised heavily. Trying to fit everything together was tricky. A lot of hacks were involved using bits and pieces."

Ahmed has been working on Mambot for around a year, using the little free time he has. "There were many moments of desperation, where I wanted to abandon the whole build," he admits. "Perseverance was the key to continue."

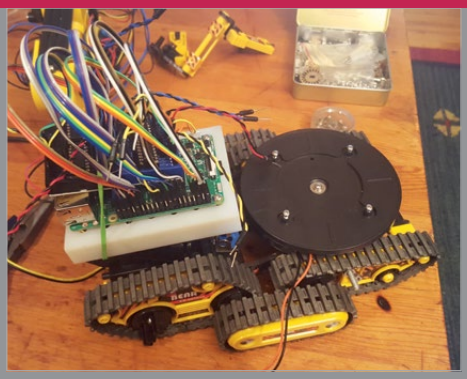
Pi programming

Mambot's software is written primarily in Python. "I used Python before now and then to automate tasks around the house," says Ahmed, "but this is my first major Python project." Other programming work included the creation of an Android app (in Java) which, as well as offering

BUILD A MULTIFUNCTIONAL ROBOT



>STEP-01
All-terrain chassis
After experimenting with a robot arm on a two-wheeled chassis, Ahmed opted to use the caterpillar-tracked base from an OWI ATR kit. He mounted the circular arm base and Raspberry Pi 3 on it.



>STEP-02
Motor drivers
To connect all the add-ons, such as a speaker, mic, and ultrasonic sensor, Ahmed used every available GPIO pin. Mambot's motors are controlled via four L293D dual H-bridge drivers.

>STEP-03
Camera mount
After reattaching the manipulator arm to its circular base and wiring it up, Ahmed placed a basic mount on the top of the gripper head to hold the Pi Camera Module for video streaming.

remote control of the robot and arm, acts as a hub for accessing all Mambot's features.

"I started by adding gamepad control first. Then I thought, why not write an app for it?, so I did. The voice control was particularly challenging. I use Snowboy hotword to issue voice commands. It works great in a quiet environment."

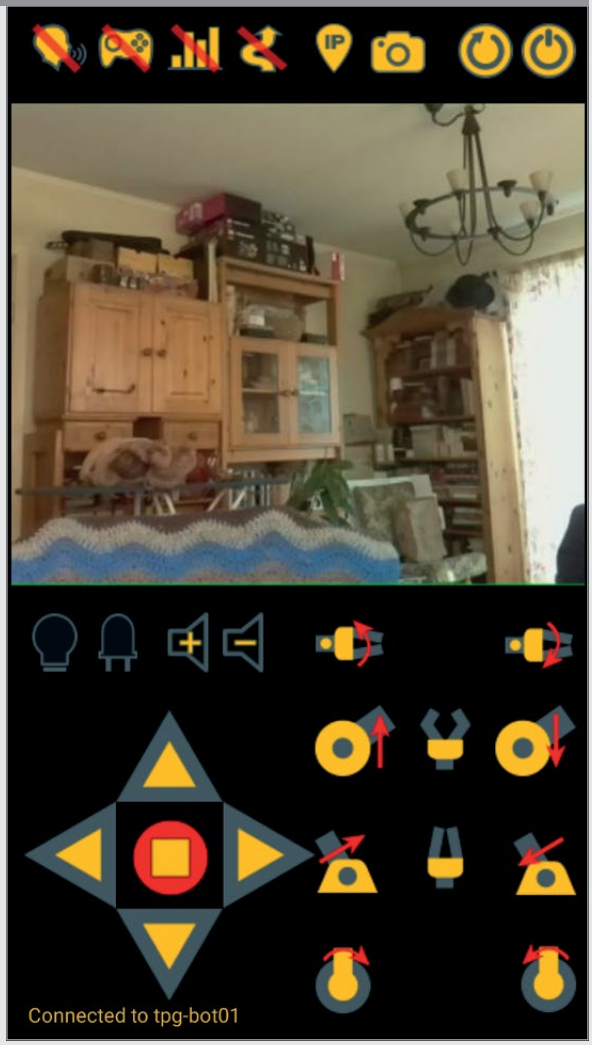
Everything is handled by a Raspberry Pi 3. "As I kept on adding features, I quickly realised that running everything on a single Pi could be problematic. Enter multithreading." After running the main Bluetooth routine on the Pi to accept a connection from the Android app, and start video streaming and the web app server, you can easily switch on/off the features you want. "Each feature runs on its own thread. The Pi handles this nicely. For example, you can control Mambot from the app while someone else is controlling it from the gamepad at the same time."

Following orders

With the eAccounting integration, Mambot listens for incoming orders and when one is received, it matches it with the job that needs to be carried out. "Say the order is to pick up an item from a warehouse or perform a service like sweeping the floor. Mambot performs the order, updates, and reports back to the system."

> "I started by adding gamepad control first. Then I thought, why not write an app for it?, so I did"

Mambot has another neat trick up its sleeve: using machine learning, it can predict when the next order will arrive. "Before the time comes, Mambot moves to the location where the predicted order is supposed to be carried out." If it arrives, Mambot performs the task; if not, it learns from this to improve its predictions in the future. "The more orders you send to the system, the more accurate the prediction is."



Above As well as offering full control of the robot, and a live video stream, the Android app enables you to turn Mambot's many features on and off

DMITRY IVANOV

Born in Russia, Dmitry is a software engineer. His son was born in Prague and he now lives in the US with his wife.

magpi.cc/2jy01v0

The lights are divided into four groups of three infrared LEDs, a 27 Ω resistor and a TIP120 transistor
FruitNanny uses a Pi NoIR camera module. It also has a DHT22 sensor to detect temperature and humidity
Dmitry has made the case model available, but he wishes it were bigger and had more ventilation holes

FRUITNANNY

Rather than throw a tantrum when he failed to find the perfect baby monitor for his newborn, **Dmitry Ivanov** decided to get creative

Quick Facts

- Dmitry bought his first Raspberry Pi in 2013
- He wrote programs that communicate with sensors on it
- FruitNanny taught him 3D modelling, soldering, and web development
- Most parts were bought from Adafruit and Amazon
- The system is based on Raspbian

Baby monitors have grown up fast. Once confined to audio, they now have all manner of gubbins inside them, from cameras and night vision to temperature readings, two-way talk, and even lullabies. For many parents, they're an essential tool for ensuring a baby is comfortable and safe. But although there are so many on the market, none of them suited Dmitry Ivanov. So he grabbed a Raspberry Pi and made his own.

Called FruitNanny, the invention essentially began with a camera-connected Pi stuffed inside a plastic lunchbox. "I'd ordered the Pi NoIR module and a microphone and started to experiment," he tells us. "I played with different programs and tools, but most of them didn't work."

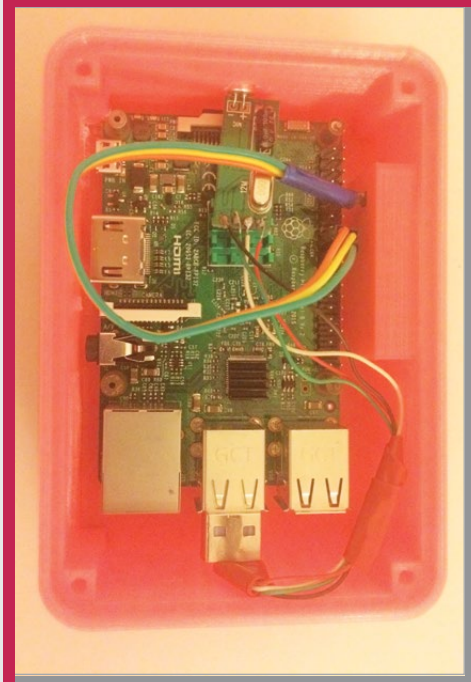
He found the original Pi wasn't powerful enough for the job and switched to a Pi 3. "I spent lots of sleepless nights trying to find the right combination," he continues. "But when I finished a proof of concept with a working setup in a lunchbox, I started to think about a case and a proper web application to combine information from sensors and media streams."

As a bare minimum, Dmitry wanted his baby monitor to stream audio and video to his PC without latency. He also wanted it to show the current temperature and humidity, work at night, and have a quiet mode where it was possible to see the audio streams but not hear them. Sticking with the NoIR camera and a cheap iPhone lens to widen the viewing angle, he added a DHT22 sensor to gather the temperature and humidity data. He also used twelve infrared LEDs for night vision and added resistors.

Custom case

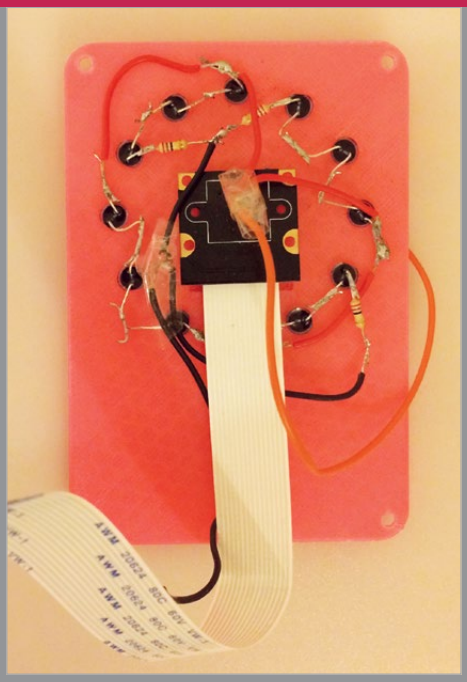
"I started to design the case too," he says. "I had several cases for Raspberry Pi, but I couldn't fit all of the hardware inside. I wanted something that looked pretty and not boring like almost every other baby monitor." He considered making it in the shape of a toy like Ironman or a Minion. "But I soon realised that I don't have a designer's talent. I tried 3D modelling with SketchUp and a

THE STATES OF FRUITNANNY



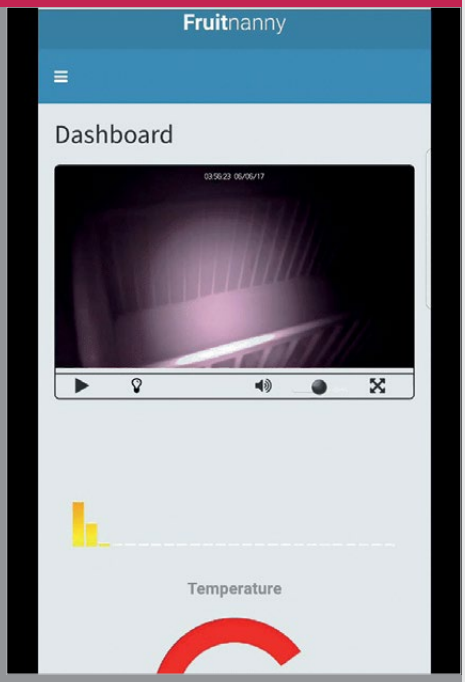
>STEP-01
A tight squeeze

The Raspberry Pi 3 is placed within the specially printed case. The sensor, transistors, and LEDs are connected to the GPIO pins; the Camera Module to CSI; and microphone to USB.



>STEP-02
The case lid

The case lid is fitted with twelve LEDs. The Camera Module – equipped with an iPhone lens – is placed in the centre hole. The lid is screwed to the case.



>STEP-03
Accessing the stream

FruitNanny uses a custom web UI and works with Windows, Linux, Android, and macOS. The dashboard allows the video feed to be viewed, along with the current temperature and humidity.

3D printer for the first time and after several failed attempts and with the help of a friend, Christos, printed a simple rectangle, which worked well."

The case is actually in four parts. The Pi and the electronics are fitted in the main part of the case and a cover is placed over the top. There is a cap for easy access to the Ethernet port of the Pi and a DHT22 cradle which isolates the sensor from the Pi and protects it from heat. Fitting the electronics together proved relatively straightforward. The software was a little trickier.

"I had used a UV4L video driver at the beginning because it was easy to install and configure," he recalls. "But it's a proprietary product and it wasn't easy to customise. I wanted to add my own video settings and extended web UI, so I decided to use something different. Since I needed a real-time media stream without latency, I found an amazing project from Meetecho, called the Janus WebRTC Gateway. I took this, added GStreamer and several scripts, and tied everything up with the Node.js web application."

Since the FruitNanny has sensors and lights and makes use of WiFi, it uses a 2A power adapter

The baby monitor worked a treat, providing an affordable and secure video baby monitor that Dmitry could potentially customise in the future. Yet he admits he only used it for a few months: "When my son turned one, we started to use it very rarely." Even so, he says his head is now full of new projects. "I'm also still going to work on the FruitNanny occasionally to help people in the same situation I was in."

GIORGIO GILESTRO

Dr Gilestro heads up a research laboratory at the Department of Life Sciences at Imperial College London.
magpi.cc/2i3vTHt

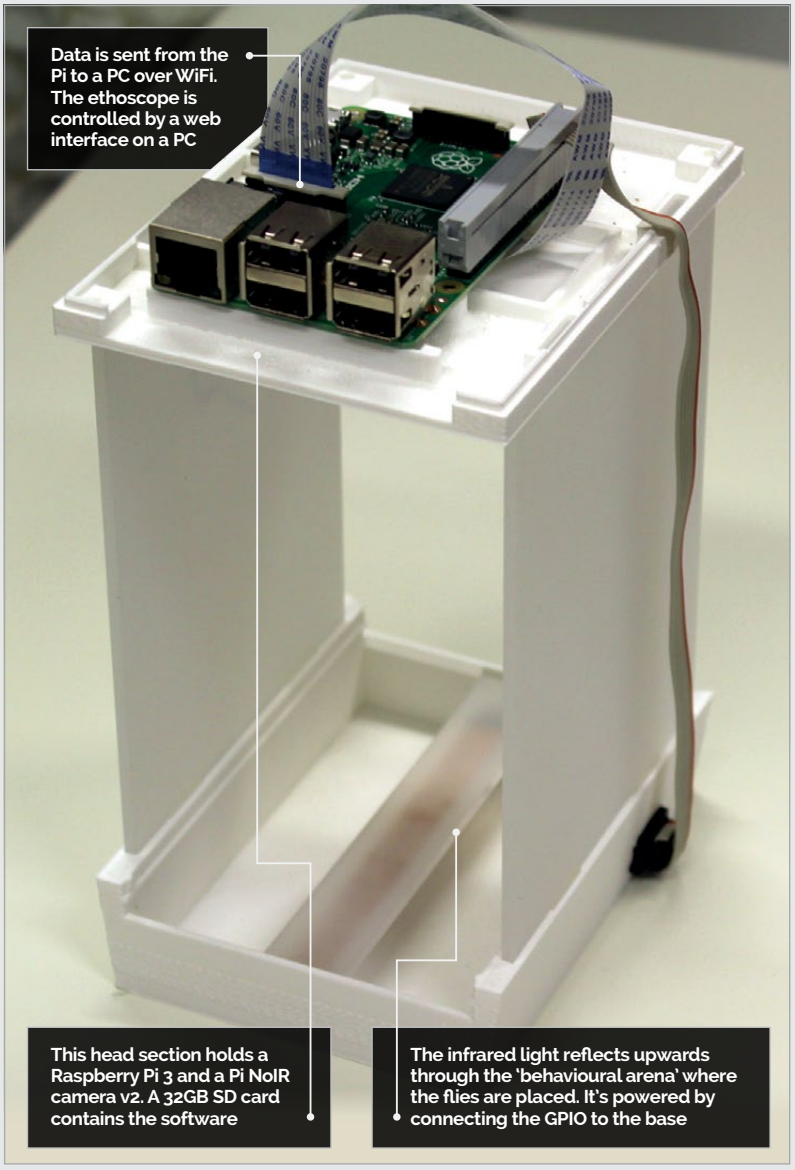
ETHOSCOPE

Scientists have created mini robotic labs powered by Raspberry Pi to test the behaviour of flies – and learn more about humans

Quick Facts

- They help scientists gain insights into human illnesses
- The ethoscope records and classifies flies en masse
- It can monitor fly behaviour and study responses
- The Pi-based ethoscope can be built for £100

The Raspberry Pi isn't quite capable of performing complex brain surgery (at least not yet), but that doesn't mean it can't help scientists work out how our minds are wired. So when a group of researchers looked for a low-cost way of conducting studies in neuroscience, they turned to our favourite computer. The result is a machine with the potential to make ground-breaking discoveries about common human behaviour. And its secret ingredient? A load of flies, of course.


Data is sent from the Pi to a PC over WiFi. The ethoscope is controlled by a web interface on a PC
This head section holds a Raspberry Pi 3 and a Pi NoIR camera v2. A 32GB SD card contains the software
The infrared light reflects upwards through the 'behavioural arena' where the flies are placed. It's powered by connecting the GPIO to the base

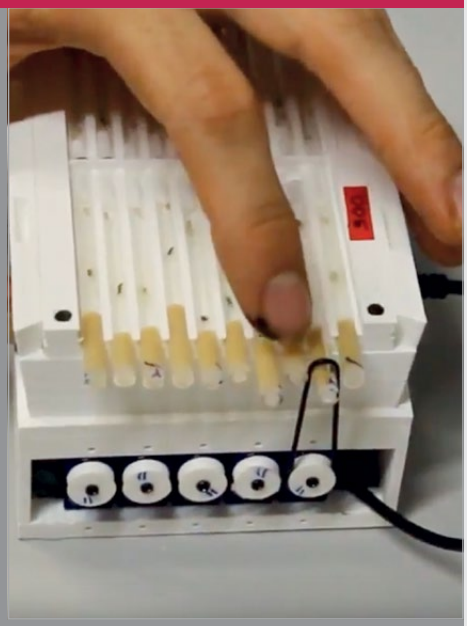
Behavioural arena

Dr Giorgio Gilestro and his colleagues from Imperial College London have used the Raspberry Pi to create what they call an ethoscope: a device that can not only track animal behaviour using open-source hardware and software, but profile it using machine learning algorithms. They use fruit flies within their studies because they are similar to humans in genetic and behavioural terms: they can be used to study mental and physical human diseases and give insights into sleeping and socialising.

But instead of manually watching the flies and scoring their movements, as has been the case in the past, the Pi-based ethoscope is able to process and analyse real-time video. In doing so, it allows scientists to automate such time-consuming processes. "We can also study hundreds or maybe thousands of flies at once because [the ethoscopes] are so small and cheap to maintain," explains Giorgio. "By using the Pis, we have enough computer power to analyse their behaviour using video imaging and we can be wallet-friendly at the same time."

At first, the group used USB webcams connected to desktop computers running software that would analyse the behaviour of the

WATCHING THE BEHAVIOUR OF FLIES



>STEP-01
Setting it up

A total of 20 flies are placed into the 20 3D-printed tubes that make up this particular behavioural arena. The unit is then inserted into the bottom of the ethoscope.

>STEP-02
Monitoring automatically

Software built on top of Linux and Python makes use of the Pi NoIR camera and begins to gather data. A web interface controls the device and allows the flies to be watched.

>STEP-03
Wake up!

In the sleep study, the ethoscope will work out when a fly appears to be sleeping. This added module can flip the tube to wake it up and see what happens.

flies being filmed. "This was very accessible because almost everyone has a computer and a webcam, but it wasn't very scalable or user-friendly," Giorgio says. "There was also an issue of people running the program on different computers and hardware." Using the Pis got around this problem and the scientists, led by PhD student Quentin Geissmann, eventually came up with a scalable device.

Right Dr Gilestro's laboratory has 80 Pi-powered ethoscopes set up within it

Bottom Right As well as 3D-printing the cases, it's possible to make the ethoscope from LEGO or cardboard

Eight behavioural arena decks have been created for research into areas such as feeding, sleep patterns, and decision-making. It's certainly proving to be revolutionary ("it's been very well received in the community," he adds) and because the ethoscope is open source and the full instructions are online, it's been quick to take off. In actual fact, there is already talk of future iterations. "It's almost like a commercialised product," Giorgio tells us.

> "Research into areas such as feeding, sleep patterns, and decision-making"

After deciding to use a 3D-printed modular design for the body of the ethoscope, they were able to place a Raspberry Pi on top, connected to a downward-facing camera. The idea was to film a 'behavioural arena' at the bottom, filled with flies and lit by an infrared LED.

SET UP PISERVER ON DEBIAN WITH RASPBERRY PI DESKTOP

Boot multiple Raspberry Pi devices at once using a PC/Mac computer running Debian with Raspberry Pi Desktop

You'll Need

- Raspberry Pi 3
- PC or Mac
- Debian with Raspberry Pi Desktop
- Raspbian

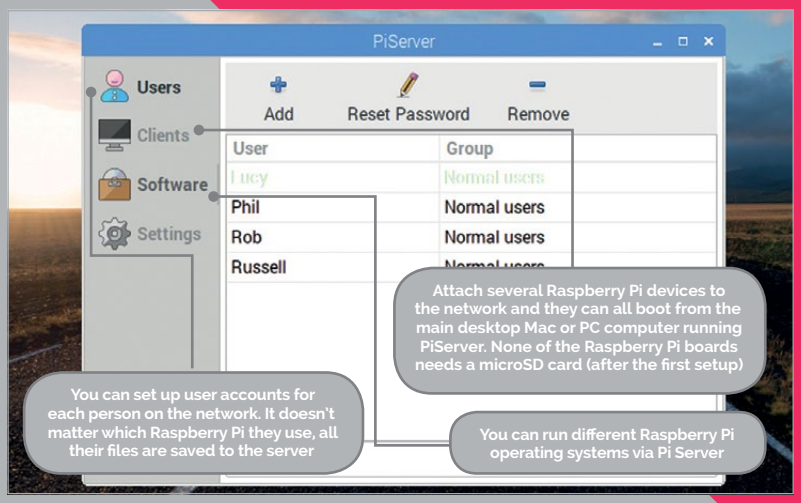
Debian with Raspberry Pi Desktop is an operating system built by the folks at Raspberry Pi, and it has just been upgraded to the Debian Stretch edition.

It's a great way to experiment with the clever Raspberry Pi environment, including all its specialist coding and resource tools, on old hardware.

However, this new update brings a really handy new tool called PiServer. Developed by the Raspberry Pi team, this piece of software enables you to boot Raspberry Pi devices from a Mac or PC running Debian with Raspberry Pi Desktop.

The idea is to use an old PC or Mac computer to boot multiple Raspberry Pi devices without requiring a microSD card for each Raspberry Pi 3 (only Raspberry Pi 3 boards support network boot at the moment).

PiServer is perfect for classrooms and coding groups. Users can log in to their account from any Raspberry Pi on the network, and access their saved files and programs. And you don't need microSD cards for your Raspberry Pi.


PiServer
Users
Clients
Software
Settings
Add
Reset Password
Remove
User
Group
Phil
Normal users
Rob
Normal users
Russell
Attach several Raspberry Pi devices to the network and they can all boot from the main desktop Mac or PC computer running PiServer. None of the Raspberry Pi boards needs a microSD card (after the first setup)
You can set up user accounts for each person on the network. It doesn't matter which Raspberry Pi they use, all their files are saved to the server
You can run different Raspberry Pi operating systems via Pi Server

HOW TO: SET UP PI SERVER

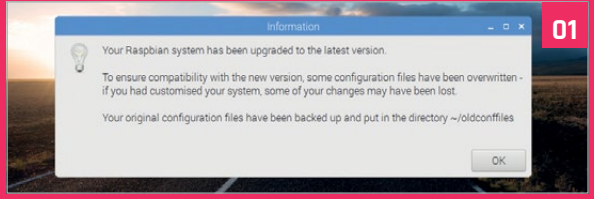
>STEP-01
Update to Stretch

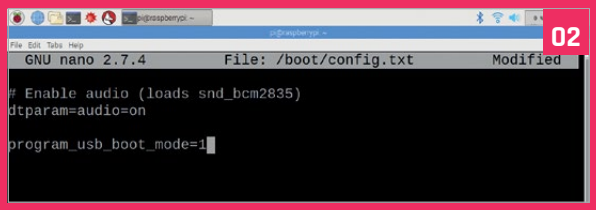
You'll need to install Debian with Raspberry Pi Desktop on an old Mac or PC desktop or laptop. If you haven't already installed the Raspberry Pi operating system on a Mac or PC, read this guide (**magpi.cc/2wkkThL**) If you've installed it previously, you'll need to upgrade to Stretch, so open a Terminal window and enter:

```
sudo nano /etc/apt/sources.list
sudo nano /etc/apt/sources.list.d/raspi.list
```

In both files, change every occurrence of the word 'jessie' to 'stretch'. When that's done, enter the following commands:

```
sudo apt-get update
sudo dpkg --force-depends -r libwebkitgtk-3.0-common
sudo apt-get -f install
sudo apt-get dist-upgrade
sudo apt-get install python3-thonny
sudo apt-get install sonic-pi=2.10.0~repack-rpt1+2
sudo apt-get install piserver
sudo apt-get install usbbootgui
```


Information
Your Raspbian system has been upgraded to the latest version.
To ensure compatibility with the new version, some configuration files have been overwritten - if you had customised your system, some of your changes may have been lost.
Your original configuration files have been backed up and put in the directory ~/oldconffiles
OK
01



>STEP-02
Set up network boot

Now you need to set up network boot on each Raspberry Pi 3 you intend to use. For this, you'll need a microSD card with a fresh installation of Raspbian. You only need the microSD card to enable network boot.

Boot the Raspberry Pi and enter the following:

```
sudo apt-get update && sudo apt-get upgrade
sudo nano /boot/config.txt
```

Add this line to the end of the file:

```
program_usb_boot_mode=1
```

Save and quit (**CTRL+O**; **CTRL+X**) and reboot your Raspberry Pi.

```
sudo shutdown -r now
```

Check it with:

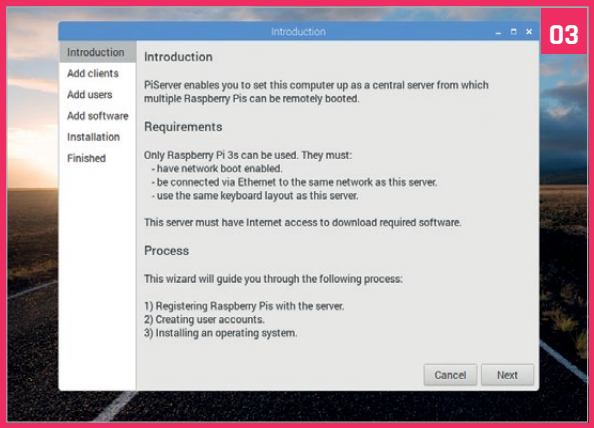
```
vcgencmd otp_dump | grep 17:
```

Ensure the output says '17:3020000a'. The client configuration is almost done. The final thing to do is to use:

```
sudo nano /boot/config.txt
```

...and remove the **program_usb_boot_mode** line from **config.txt** (make sure there is no blank line at the end). See 'Network Boot your Raspberry Pi' for more information (**magpi.cc/2BUVCd7**) on setting up network boot.

Finally, shut the client Raspberry Pi down with **sudo shutdown -h now**. Remove the microSD card.


03
Introduction
Introduction
Add clients
Add users
Add software
Installation
Finished
Introduction
PiServer enables you to set this computer up as a central server from which multiple Raspberry Pis can be remotely booted.
Requirements
Only Raspberry Pi 3s can be used. They must:
- have network boot enabled.
- be connected via Ethernet to the same network as this server.
- use the same keyboard layout as this server.
This server must have Internet access to download required software.
Process
This wizard will guide you through the following process:
1) Registering Raspberry Pis with the server.
2) Creating user accounts.
3) Installing an operating system.
Cancel
Next

>STEP-03
Open PiServer

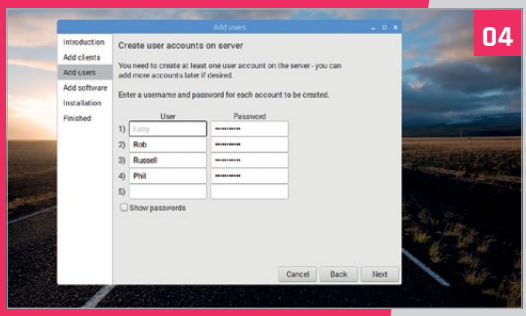
Back in Debian with Raspberry Pi Desktop, open the PiServer app (Preferences > PiServer). Read the Introduction and click Next.

Make sure the Raspberry Pi you want to boot has the microSD card removed, and an Ethernet cable attached. Connect the power supply to the Raspberry Pi. You should see a MAC address (six hexadecimal digits) appear in the list.

Make sure a tick is next to the MAC address of your Raspberry Pi and click Next.

>STEP-04
Create user

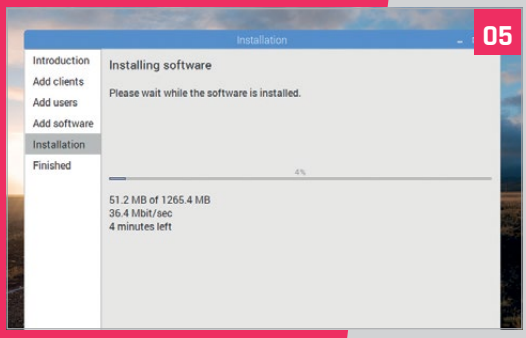
Now enter a name for the user who is going to connect. You can add multiple users and passwords (one for each child in a school, for example). Fill out the User and Password fields for each user and click Next.



>STEP-05
Install OS

Now choose the operating system you wish to install on the Raspberry Pi. By default you have two options:

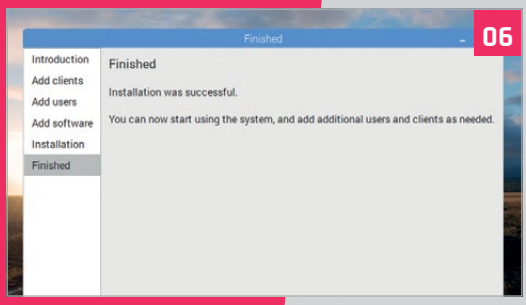
Raspbian
Raspbian Lite



You can also upload operating systems from local files or enter a URL. Make sure Raspbian (not Raspbian Lite) is selected for our test, and click Next. Wait while it installs the software (it took us around five minutes – it depends on your network speed).

>STEP-06
Run the Raspberry Pi

With the installation finished, you'll see the main interface (as shown in the annotated image on page 38). On the sidebar you will see Uses and Clients (use the Add and Remove options to manage both). You can also use the Software option to run different operating systems. Raspberry Pi devices connected to the network will boot into the selected operating system, and users can log in using their name and details.



MIKE'S PI BAKERY

MIKE COOK

Veteran magazine author from the old days and writer of the Body Build series. Co-author of *Raspberry Pi for Dummies*, *Raspberry Pi Projects*, and *Raspberry Pi Projects for Dummies*.
magpi.cc/259aT3X

RING THE CHANGES

Ring in the New Year with your very own tower of bells

You'll Need

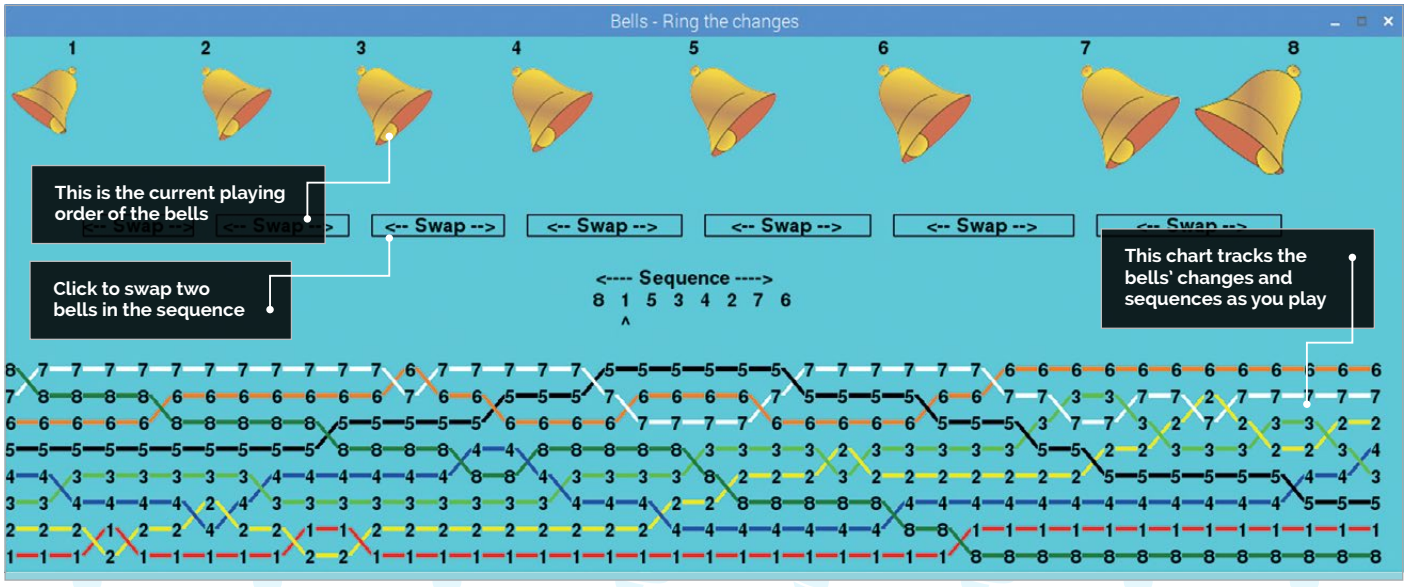
- Raspberry Pi 3
- A display at least 1260 pixels wide

Once, when writing a Raspberry Pi book, your author used a section heading of 'Ringing the changes', to signify that the section was going to look at variations on what went before. He was astonished when his American editor had no idea what that term meant. In fact, the question 'what is the term for a bell ringer?', if asked on the popular TV quiz *QI*, would provoke the klaxon if you gave the answer 'campanologist', as that is what the study of bells is called. The correct answer would be 'bell ringer'.

Bell ringing has a lot more to do with mathematics than you might first think and, despite its ancient origin, it is an ideal topic to computerise.

Ways of ringing

While there are many different methods of ringing a set of bells, the two basic ones are change ringing and method ringing. In short, all the bells are rung in turn; this is known as a round. With change ringing, two of the bells in a round swap places for the next round. These bells must be adjacent in the current sequence, because of the very high mass of the bells which results in a limited ability to delay or advance the ringing position in a sequence. Method ringing is similar, but more than one pair of bells can change between any one round. In both systems they start and end with a round going from the highest bell, called the Treble, to the lowest, the Tenor. The bells



are numbered, starting with 1 for the Treble. Note that this is the reverse of many systems in music, where the lowest number is reserved for the lowest note.

Normally, there are anything between four and twelve bells, with eight being popular. If tuned, they are usually in the key of C. There are many hundreds of different methods, but the basic rule is that the round starts with the sequence 1 to the highest bell number and ends on that sequence as well, but no other sequence is permitted to repeat. Ideally, all possible sequences must be used; this is called an 'extent'. But, for twelve bells there will be 12! (12×11×10×9×8×7×6×5×4×3×2×1) combinations, and that would take over 35 years to ring. The record currently stands at 21 216 changes on the twelve bells of South Petherton Church, near Yeovil, which took 14 hours 26 minutes to complete.

It might come as a surprise, but the dedicated bell ringer is not interested so much in how it sounds, but in learning how to ring a specific pattern. In fact, a lot of the sequences are musically unremarkable and sound a bit like random ringing, even to the trained ear. The real appeal is in the physicality and discipline in getting it right. However, our curiosity got the better of us and we wanted to hear what it sounded like, so we wrote this simulator/player. It simulates change ringing, in that you can direct which bells to swap, but it will also play preprogrammed sequences where 'one man and his mouse' would be hard put to keep up any live determination of sequences. These sequences delight in names like Plain Bob Major, Bristol S Maximus, and Grandsire Cinques, to name but three.

Documenting a ring

These rings are documented by writing each successive sequence of bells, with lines connecting the bell numbers so you can see how they change. However, normally there is only one line for one bell to follow, and not all bells are numbered, as shown in **Figure 1**. This is understandable, because it is meant for one bell/player, and they just need to know if they have to keep their ringing position the same, or move up or down in the sequence. This shorthand, however, often makes it difficult for a beginner to follow. The full diagrams are normally shown as a vertical list; a full list, resembling braid, is shown in **Figure 2**. Alternatively, these lists of sequences can be shown horizontally, known as a roller, **Figure 3** (overleaf), or even circularly as a ring, **Figure 4**. All these pictures were generated by the free-to-use toolkit to be found at **magpi.cc/2jCpOlt** and reproduced here by kind permission of the author Steve Scanlon.

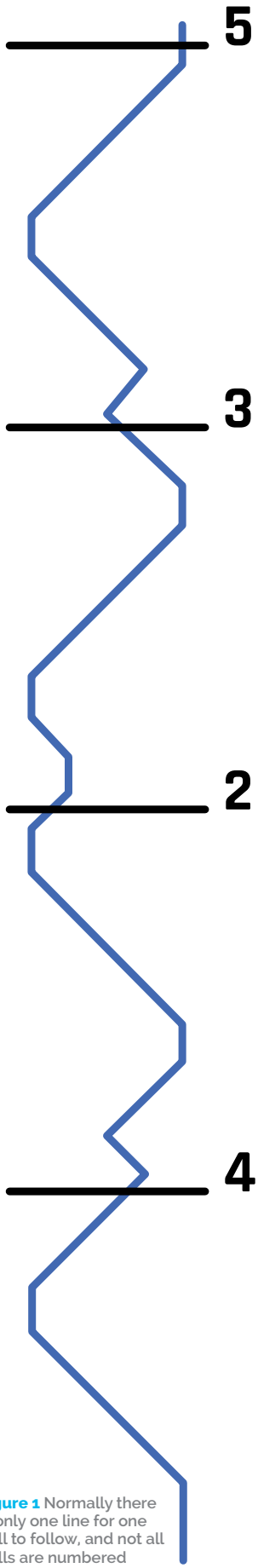


Figure 1 Normally there is only one line for one bell to follow, and not all bells are numbered

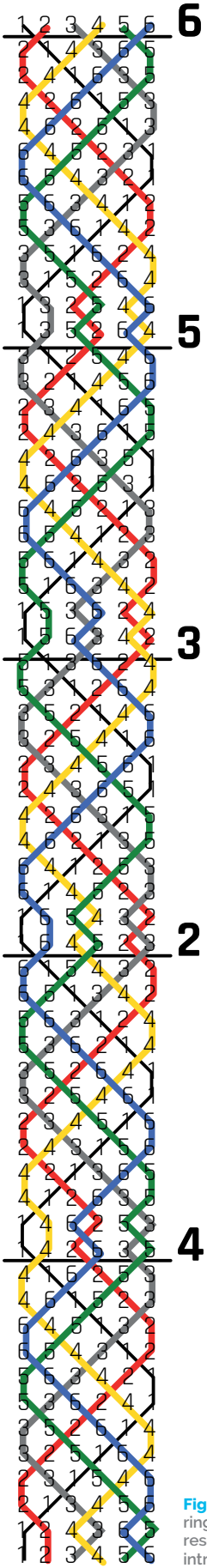


Figure 2 A full ringing diagram resembles an intricate braid

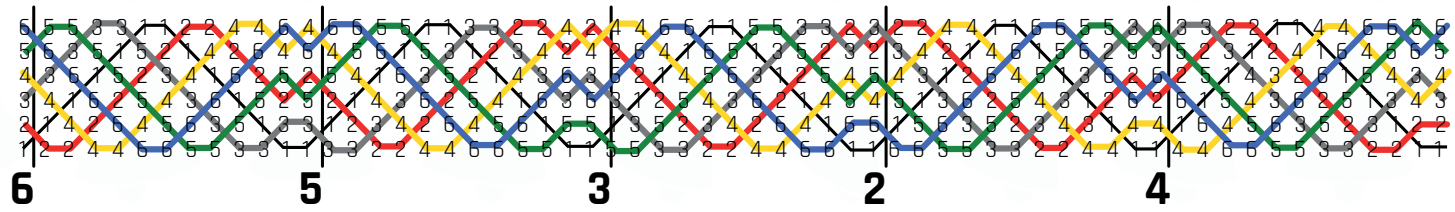


Figure 3 Sequences can be shown horizontally, known as a roller

Preparing the resources

The first thing we did was to prepare the graphics. We found a royalty-free image of a bell on the internet and rotated it through 90° in eleven stages. At each stage, we used a photo editing package to move the bell's clapper; the results are shown in

> We want the bell to swing about the pivot point at the top, in order for it to look like a realistic swing

Figure 5. The thing to note here is that we want the bell to swing about the pivot point at the top, in order for it to look like a realistic swing. So we have to plot each bell, in the animation, at a different position in the x direction, so that the pivot point ends up in the same spot. These images were named **b0.png** to **b10.png** and put in a folder called **swing**. The software would then scale this set of images so that each bell had its own sized animation sequence.

Then the sound of eight bells were put in a folder called **sounds** and named **0.wav** to **7.wav**. We started with bells recorded from a MIDI sound generator, but eventually replaced these with live recordings, done by a friend, of the bells in St Matthias Church, Leeds.

Finally, we prepared some method files based on classic methods. These are simple text files and consist of the sequence of each round, with a row of '**-**' signs being used as a comment or blank line to break things up and make it easer to see what is going on. The two methods we have encoded like this are 'Plain Bob Minor' and 'New Year Delight Minor' and can be found along with the software in the GitHub repository.

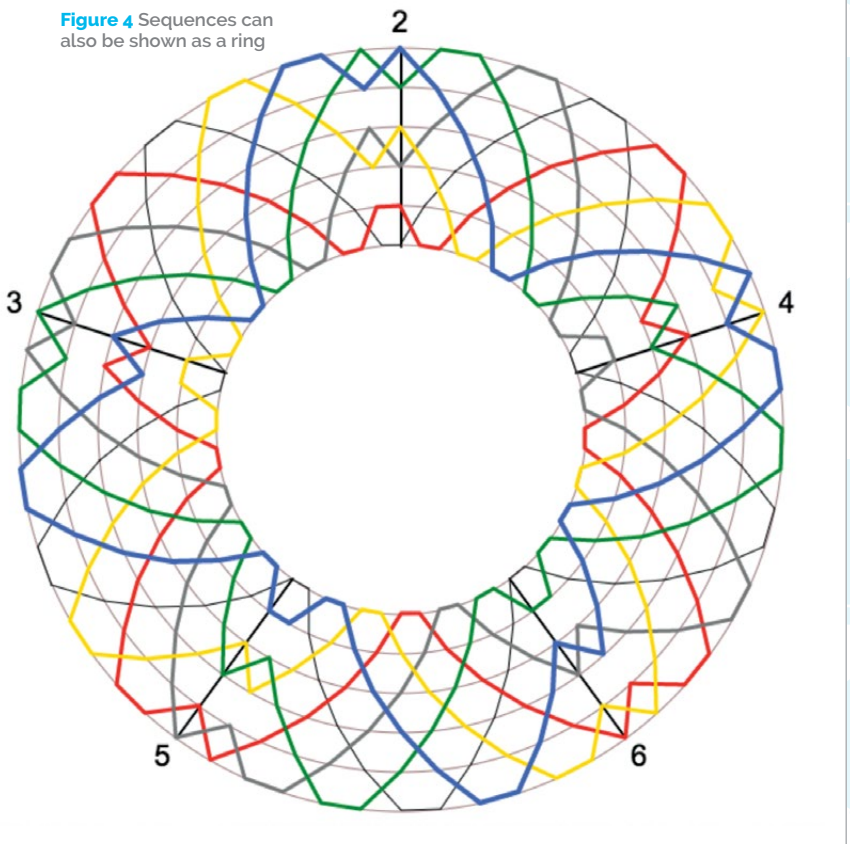


Figure 4 Sequences can also be shown as a ring

The software

The program, **bells_play.py**, uses the Pygame framework. Most of the parameters – like colour, speed, and the control variables – are defined at the start of the code, just before the **`main`** function. The **`loadResources`** function does the scaling of each animation sequence and, as this takes some time, when each bell has been processed it is displayed on the screen, to prevent having a long time where nothing seems to happen. It is important to the visual effect that the bell goes through an animated sequence and doesn't just flip from a bell on one side to a bell on the other, even though each image spends very little time on the screen. The **`handleMouse`** function sees if any of the 'swap icons' has been clicked and the **`checkForEvent`** function is where most of the other control takes place in response to keyboard presses. The drawSequence function displays the current order of the bells, and the **`showRing`** function points to the bell currently being rung.

Using the software

The software starts up in the stopped mode; pressing the **R** key will start it ringing, with the **S** key stopping the ringing at the end of the current round. It can use four to eight bells, selected by simply pressing the number keys on the keyboard. The **+** and **-** keys control the speed of the ringing and the **F** file key brings up a dialogue box to allow

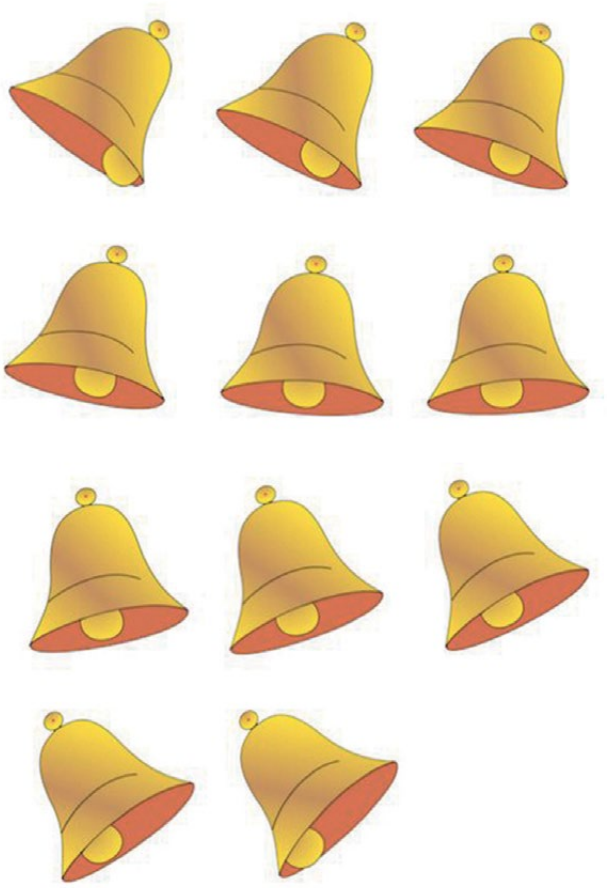


Figure 5 An array of frames of the bells in motion

you to load in a specific ring. The **A** key will turn on and off the automatic swap mode; this is where the swap position is generated at random. When the bells are running, clicking on one of the Swap boxes between two bells will swap then at the end of that round. All the time, the map or documentation of the sequence history is displayed scrolling along the bottom of the window. We liked to turn on the automatic swap mode for a time, then turn it off and manually swap bells to get the sequence back to the start.

Taking it further

For a start, the bell sounds are all mono – it would be interesting to space these out in a stereo field. Also, we have not implemented the 'calling' of the bells; that is, calling out the two that need swapping in a round with change ringing. Calling is done in two ways: calling up and calling down. The latter is the simplest, a call of 'Six to Seven' will swap bell numbers six and seven; the only complication is that the highest and lowest bells are called 'Treble' and 'Tenor'. Such a list could be taken to any tower and called. Finally, we urge you to have a good look at the toolkit from Steve's website. If that piques your interest, why not see if there is a bell ringing group in your area and try the real thing?

bells_play.py

Language
>PYTHON 3

DOWNLOAD:
magpi.cc/1NqJjmV

PROJECT VIDEOS
Check out Mike's Bakery videos at:
magpi.cc/1NqJnTz

```
001. import pygame, time, os, copy, random
002. from tkinter import filedialog
003. from tkinter import *
004.
005. pygame.init()  # initialise graphics
     interface
006. pygame.mixer.quit()
007. pygame.mixer.init(frequency=22050,
     size=-16, channels=2, buffer=512)
008.
009. os.environ['SDL_VIDEO_WINDOW_POS'] =
     'center'
010. pygame.display.set_caption("Bells - Ring the changes")
011. pygame.event.set_allowed(None)
012. pygame.event.set_allowed([pygame.KEYDOWN,pygame.QUIT,
013.                           pygame.MOUSEBUTTONDOWN])
014. screenWidth = 1260 ; screenHight = 482
015. screen = pygame.display.set_mode([screenWidth,screenHight],0,32)
016. textHeight=26 ; hangY = 30
017. font = pygame.font.Font(None, textHeight)
018. swingSpeed = 0.01 # animation rate
019. bellX = [60,180,320,460,620,790,973,1160]
020. backCol = (0,255,255) # background colour
021. trails = [(255,0,0),(255,255,0),(0,255,0),(0,0,255),
022.           (0,0,0),(255,128,0), (255,255,255), (32,120,0)]
023. speed = 0.4 ; running = False ; automatic = False
024. random.seed() ; ringLength = 8 ; filePlay = False
025.
026. def main():
027.    global lastSequence, swapFrom, running, bellSequence
028.    drawLables()
029.    resetSequence()
030.    loadResources()
031.    print("Ring in the new - press R to ring")
032.    print("S to stop - F to play a file - C to ring the changes")
033.    while True:
034.       checkForEvent()
035.       if filePlay :
036.          if running:
037.             drawControls()
038.             lastSequence = fSeq[0]
039.             i=-1
040.             while i < int(len(fSeq))-1 and running:
041.                i += 1
042.                if int(len(fSeq[i])) > 0 :
043.                   if int(fSeq[i] !=0):
044.                      bellSequence = fSeq[i]
045.                      playPeal()
046.                      drawSequence()
047.                      lastSequence = copy.
     deepcopy(bellSequence[:])
048.             running = False
049.       else:
050.          if running:
051.             playPeal()
052.             lastSequence = copy.deepcopy(bellSequence[:])
053.             if swapFrom != -1: # if we need to swap
054.                bellSequence[swapFrom],bellSequence[swapFrom+1]=b
     ellSequence[swapFrom+1],bellSequence[swapFrom]
055.             swapFrom = -1 # remove swap call
```

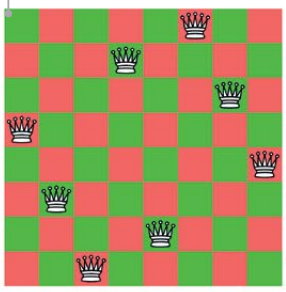
```
            drawControls()
            drawSequence()

def playPeal():
   global swapFrom, speed
   for ring in range(0,ringLength):
      showRing(ring)
      swing(bellSequence[ring])
      if ring ==2 and automatic and not(filePlay): # random swap
         swapFrom = random.randint(0,ringLength-2)
         drawControls()
         pygame.display.update()
      checkForEvent()
      time.sleep(speed)

def setMode(mode):
   global filePlay
   filePlay = mode
   if filePlay:
      root = Tk()
      root.filename = filedialog.askopenfilename(initialdir = "/home/pi",
          title = "Select bell method",filetypes = (("txt files","*.txt"),
          ("all files","*.*")))
      loadFile(root.filename)
      root.withdraw()
   else :
      pygame.display.set_caption("Bells - Ring the changes")
      resetSequence()

def loadFile(fileName):
   global fSeq, ringLength
   nameF = open(fileName,"r")
   pygame.display.set_caption("Playing - "+fileName)
   sequenceFile = nameF.readlines()
   ringLength = int(len(sequenceFile[0]) / 2)
   fSeq = [] ; k=-1
   for i in sequenceFile:
      k +=1
      ns = []
      for j in range(0,int(len(sequenceFile[k])),2):
         if i[j:j+1] != '-' and i[j:j+1] != '\n':
            n = int(i[j:j+1])-1 # to get bells 0 to 7
            ns.append(n)
      fSeq.append(ns)
   fSeq.append(ns) # extra line at end
   nameF.close()

def showRing(n): # indicate the current ring point
   pygame.draw.rect(screen,backCol,(524,248,185,16),0)
   drawWords("^",530+n*24,248,(0,0,0),backCol)
   pygame.display.update()

def drawControls(): # draw swap radio buttons
   pygame.draw.rect(screen,backCol,(0,160,screenWidth,20),0)
   if filePlay:
      return
   for n in range(0,ringLength-1):
      if n == swapFrom:
         pygame.draw.rect(screen,(128,32,32),(bellX[n]+10,160,bellX[n+1]-bellX[n]-20,20),0)
         drawWords("<-- Swap -->",bellX[n]+10+n*6,160,(0,0,0),(128,32,32))
      else:
         drawWords("<-- Swap -->",bellX[n]+10+n*6,160,(0,0,0),backCol)
         pygame.draw.rect(screen,(0,0,0),(bellX[n]+10,160,bellX[n+1]-bellX[n]-20,20),1)

def drawSequence(): # display bell sequence
   screen.set_clip(0,260,screenWidth,screenHight-260)
   screen.scroll(-30,0)
   screen.set_clip(0,0,screenWidth,screenHight)
   for n in range(0,ringLength):
      t = -1 ; j = 0
      while t == -1:
         if bellSequence[j] == lastSequence[n]:
            t = j
         j +=1
      pygame.draw.line(screen,trails[lastSequence[n]],(screenWidth-50,screenHight-16-n*24),(screenWidth-30,screenHight-16-t*24),4)
   pygame.draw.rect(screen,backCol,(530,227,179,20),0)
   pygame.draw.rect(screen,backCol,(screenWidth-30,screenHight-200,16,191),0)
   for n in range(0,ringLength):
      drawWords(str(bellSequence[n]+1),530+n*24,227,(0,0,0),backCol) # horizontally
      drawWords(str(bellSequence[n]+1),screenWidth-30,screenHight-(n+1)*24,(0,0,0),backCol) # vertically
   pygame.display.update()

def drawLables():
   global textHeight
   textHeight = 26
   pygame.draw.rect(screen,backCol,(0,0,screenWidth,screenHight),0)
   for n in range(0,8):
      drawWords(str(n+1),bellX[n]-4,0,(0,0,0),backCol)
   textHeight = 36
   drawWords("<---- Sequence ---->",532,207,(0,0,0),backCol)

def swing(bellNumber): # animated bell swing
   global bellState
   if bellState[bellNumber] :
      for pos in range(1,11): # swing one direction
         showBell(bellNumber,pos,pos-1)
         time.sleep(swingSpeed)
      bellState[bellNumber] = 0
   else:
      for pos in range(9,-1,-1): # swing the other direction
         showBell(bellNumber,pos,pos+1)
         time.sleep(swingSpeed)
      bellState[bellNumber] = 1
   samples[bellNumber].play()  # make sound
```

```
160.
161. def showBell(bellNumber,seqNumber,lastBell): # show one
     frame of the bell
162.    cRect = bells[bellNumber][lastBell].get_rect()
163.    cRect.move_ip((bellX[bellNumber]-
     plotPoints[bellNumber][lastBell][0],
164.                   hangY-plotPoints[bellNumber][lastBell]
     [1]) )
165.    pygame.draw.rect(screen,backCol,cRect,0) # clear last
     bell image
166.    screen.blit(bells[bellNumber]
     [seqNumber],(bellX[bellNumber]
167.          -plotPoints[bellNumber][seqNumber][0],
168.           hangY-plotPoints[bellNumber][seqNumber][1]))
169.    pygame.display.update()
170.
171. def drawWords(words,x,y,col,backCol) :
172.         textSurface = pygame.Surface((14,textHeight))
173.         textRect = textSurface.get_rect()
174.         textRect.left = x
175.         textRect.top = y
176.         textSurface = font.render(words, True, col,
     backCol)
177.         screen.blit(textSurface, textRect)
178.
179. def loadResources():
180.    global bells, plotPoints, bellState, samples,
     swapIcon
181.    bellState = [1,1,1,1,1,1,1,1]
182.    scale = [12.0,11.0,10.15,9.42,8.8,8.25,7.76,7.33] #
     size of bell
183.    point = [(676, 63),(646, 73),(606, 73),(532,
     75),(452, 71),
184.             (380,67),(290, 71),(214, 61),(154, 57),(118,
     77),(114, 75) ]
185.    plotPoints = []
186.    bells = []
187.    for scaledBell in range(0,8):# get images of bells
     and scale them
188.       plotPoint = []
189.       bell = [ pygame.transform.smoothscale(pygame.
     image.load(
190.          "swing/b"+str(b)+".png").convert_
     alpha(),(int(792.0/scale[scaledBell]),
191.          int(792.0/scale[scaledBell]))) for b in
     range(0,11)]
192.       for p in range(0,11):
193.          p1 = int(point[p][0] / scale[scaledBell])
194.          p2 = int(point[p][1] / scale[scaledBell])
195.          plotPoint.append((p1,p2))
196.       bells.append(bell)
197.       plotPoints.append(plotPoint)
198.       showBell(scaledBell,0,0)
199.    samples = [pygame.mixer.Sound("sounds/"+str(pitch)+".
     wav")
200.                for pitch in range(0,8)]
201.
202. def resetSequence():
203.    global bellSequence, swapFrom,lastSequence
204.    bellSequence = [0,1,2,3,4,5,6,7]
205.    lastSequence = [0,1,2,3,4,5,6,7]
206.    swapFrom = -1
207.    pygame.draw.rect(screen,backCol,(0,227,screenWid
     th,253),0)
208.    drawControls()
209.    drawSequence()
210.
211. def handleMouse(pos): # look at click for swap positions
212.    global swapFrom
213.    if filePlay :
214.       return
215.    update = False
216.    if pos[1] > 160 and pos[1] < 180: # swap click
217.       for b in range(0,ringLength-1):
218.          if pos[0] > bellX[b]+10 and pos[0] <
     bellX[b+1]+10 :
219.             swapFrom = b
220.             update = True
221.    if update :
222.       drawControls()
223.       pygame.display.update()
224.
225. def terminate(): # close down the program
226.     pygame.mixer.quit()
227.     pygame.quit() # close pygame
228.     os._exit(1)
229.
230. def checkForEvent(): # see if we need to quit
231.     global speed, running,ringLength, automatic
232.     event = pygame.event.poll()
233.     if event.type == pygame.QUIT :
234.          terminate()
235.     if event.type == pygame.KEYDOWN :
236.        if event.key == pygame.K_ESCAPE :
237.           terminate()
238.        if event.key == pygame.K_RETURN and not filePlay:
     # reset sequence
239.           resetSequence()
240.        if event.key > pygame.K_3 and event.key <
     pygame.K_9 and not filePlay:
241.           ringLength = event.key & 0x0f # number of
     bells
242.           drawControls()
243.           drawSequence()
244.        if event.key == pygame.K_a : # automatic swap
245.           automatic = not(automatic)
246.        if event.key == pygame.K_r : # run bell
247.           running = True
248.        if event.key == pygame.K_s : # stop bells
249.           running = False
250.        if event.key == pygame.K_EQUALS : # reduce speed
251.           speed -= 0.04
252.           if speed < .08:
253.              speed = .08
254.        if event.key == pygame.K_MINUS : # increase speed
255.           speed += 0.04
256.        if event.key == pygame.K_c : # ring changes
257.           setMode(False)
258.        if event.key == pygame.K_f : # play a file
259.           setMode(True)
260.     if event.type == pygame.MOUSEBUTTONDOWN :
261.         handleMouse(pygame.mouse.get_pos())
262.
263. # Main program logic:
264. if __name__ == '__main__':
265.     main()
```

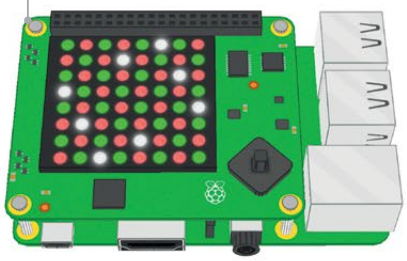
GORDON HORSINGTON

Readers of a certain age, with good memories and an interest in the BBC Micro may remember Gordon as the author of most of the BBC Telesoftware programming tutorials broadcast on BBC 2 Ceefax during the second half of the 1980s.
magpi.cc/2iZAb3b

Eight queens successfully placed on a chessboard so that they don't threaten each other; this is just one possible solution



The same solution on a standard 2D chessboard diagram, which can be converted for the Sense HAT's display



The green and red LEDs shown on the Sense HAT represent the board, and the white LEDs represent the queens. Other colours will also be used

SOLVE THE EIGHT QUEENS CHESS PROBLEM

Could you create a program to solve the eight queens puzzle for any size chessboard? If you can then you may be eligible to claim a one million dollar prize

You'll Need

- Raspberry Pi Sense HAT **magpi.cc/1TGGUt5**
- Raspberry Pi Sense HAT emulator **magpi.cc/2bscvQk**
- The eight queens puzzle on Wikipedia **magpi.cc/2iYCLGl**
- The eight queens million dollar prize **magpi.cc/2BhNo1W**

This is not a joke or a scam. There really is a prize of one million dollars waiting to be claimed by anyone who can solve the puzzle of placing n queens on an n×n chess-board so that no two queens threaten each other (where n is any number taken from the set of positive integers greater than three). If you decide to take on this challenge then your program will also have to show whether an incomplete solution to the puzzle is a subset of a complete solution. For example, you will need to demonstrate whether a set of six queens placed on and 8×8 board is a subset of a solution to placing eight queens on the same board.

If you're interested in the prize, then we'll show you how a Python program running on a Raspberry Pi with a Sense HAT can play eight queens as a game, solve the puzzle if you get stuck, and demonstrate whether an incomplete solution is a subset of a complete solution.

Our program uses the LED matrix on a Raspberry Pi Sense HAT to represent a chessboard. The program will allow you to place and replace up to eight queens on the board in the quest to find a solution. If you get stuck with an incomplete solution, then the program will solve the puzzle for you and show you where you might have needed to move any of your queens to find a complete solution.

Don't worry if you haven't got a Sense HAT on your Raspberry Pi: you can also run the program in the online Sense HAT emulator – just paste the code into it.

Can you solve the eight queens puzzle?

Eight queens is usually played on a chessboard using eight chess pawns as surrogate queens.

Placing queens on the board at random and expecting to find a solution is not a good way to play this game. There are nearly 4.5 billion ways in which it's possible to place eight queens on a chessboard (4426165368 to be precise), but only 92 of these possibilities satisfy the requirement that no two queens can threaten each other. Although all 92 solutions appear to be unique, there are in fact only twelve truly unique solutions to the puzzle. The other 80 apparently unique solutions are transformations (rotations and reflections) of the twelve truly unique solutions. Quite clearly, we're going to need a better strategy than just having a go.

When people play games like chess or draughts (checkers), they often use a combination of insight, cunning, and a game plan to defeat their opponent. One of the common strategies for these games is to control the middle of the board. This is quite a good way to play chess or draughts, but it's not the way to play eight queens. Eight queens is a game played by one person and there's no one to defeat. There has to be one queen, and only one queen, on every column and row of the board and for this reason the edges of the board can be just as important as the centre. We're going to need a different strategy – one that's better suited to playing eight queens.

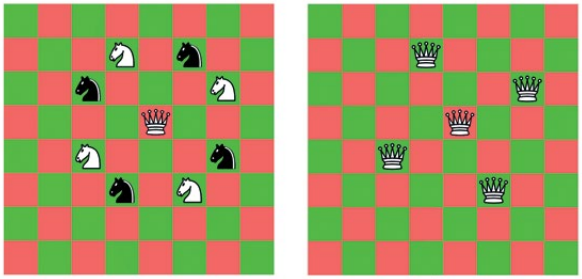


Figure 1 The knight's move is a useful strategy for placing queens on a board so that they don't threaten one another. The white queen in Figure 1a doesn't threaten any of the knights. Remove the black knights from Figure 1a and replace the white knights with queens and we have an incomplete solution with five of the eight queens on the board (Figure 1b)

Let's take look at chess and consider what happens when a knight threatens a queen. There are eight positions from which a knight can threaten a queen near the centre of the board (**Figure 1a**) and the queen cannot retaliate by removing any of the threatening knights. Don't worry about there being eight knights on the board – we're not playing chess, we're just thinking about chess moves. Placing queens on a chessboard using the knight's move to separate them can be quite a good strategy for playing eight queens. If you remove the black knights from **Figure 1a** and replace the four white knights with four queens, then no two queens are threatening each other (**Figure 1b**). We have five queens on the board and an attractive strategy. Unfortunately, as we'll see in a moment, the five queens seen in **Figure 1b** are not part of a complete solution.

It doesn't matter where you place your first queen, you can always use the knight's move to place a second one. As we'll soon see, this tactic doesn't always succeed in placing all eight queens and quite often you'll have to backtrack and move your queens around a bit before finding a solution, but it's quite a good strategy to keep in mind. Remember, even though the knight's move is useful, it's not always sufficient to complete the puzzle (**Figure 2**, overleaf).

How can the Raspberry Pi solve the eight queens puzzle using Python and a Sense HAT?

Using the knight's move strategy is one way in which a computer could tackle the puzzle, but it's not the easiest nor the best one to translate into program code because it won't find all the possible solutions. When you or I use this strategy, we tend to look at the board and the placement of the queens as a whole; we look at the empty squares as well as the queens and we use our insight into the puzzle to find a good position for our next queen. If we get stuck then we can shuffle our queens around, looking at the empty squares as well as the queens, and we can reposition the pieces taking our conceptual model of the problem into account. Insight like this is difficult to define and, without

eight_queens.py

Language
>PYTHON 3

DOWNLOAD:
magpi.cc/2krfFZq

```
001. # Eight Queens by Gordon Horsington
002. # Python 3 and Raspberry Pi Sense HAT
003. import sys, time, os
004. from sense_hat import SenseHat
005. sense = SenseHat()
006. def main():
007.     r       = [92, 0, 0]
008.     g       = [0, 92, 0]
009.     yellow  = [120, 120, 0]
010.     blue    = [0, 0, 120]
011.     white   = [120, 120, 120]
012.     empty_board = [
013.         g,r,g,r,g,r,g,r,
014.         r,g,r,g,r,g,r,g,
015.         g,r,g,r,g,r,g,r,
016.         r,g,r,g,r,g,r,g,
017.         g,r,g,r,g,r,g,r,
018.         r,g,r,g,r,g,r,g,
019.         g,r,g,r,g,r,g,r,
020.         r,g,r,g,r,g,r,g]
021.     results = [[0],[0],[0],[0],[0],[0],[0],[0],]
022.     for x in range(8):
023.         for y in range(91):
024.             results[x].append(0)
025.     find_all(results)
026.     game = [-1,-1,-1,-1,-1,-1,-1,-1]
027.     x, y, playing, display, midgame = 3, 4, True, False, False
028.     sense.set_pixels(empty_board)
029.     sense.set_pixel(x, y, blue)
030.     while playing:
031.         for event in sense.stick.get_events():
032.             if event.action == 'pressed':
033.                 if event.direction == 'up':
034.                     y, midgame = increase(y)
035.                 if event.direction == 'down':
036.                     y, midgame = decrease(y)
037.                 if event.direction == 'right':
038.                     x, midgame = decrease(x)
039.                 if event.direction == 'left':
040.                     x, midgame = increase(x)
041.                 if event.direction == 'middle':
042.                     if display:
043.                         playing = False
044.                     else:
045.                         if good_move(game, x, y):
046.                             midgame = True
047.                         else:
048.                             best = find_best(game, results)
049.                             display = show_answer(game, sense, white,
    blue, yellow, results, best)
050.                 if midgame:
051.                     sense.set_pixels(empty_board)
052.                     sense.set_pixel(x, y, blue)
053.                     display, midgame = show_game(game, sense, white,
    blue)
054.     sense.clear()
055.     sys.exit()
056. def show_answer(game, sense, white, blue, yellow, results, best):
057.     for count in range(8):
058.         if game[count] >= 0:
059.             sense.set_pixel(count, game[count], blue)
060.     for count in range(8):
061.         if results[count][best] == game[count]:
062.             shade = white
063.         else:
064.             shade = yellow
065.         sense.set_pixel(count, results[count][best], shade)
```

```
066.             game[count] = -1
067.         return True
068. def show_game(game, sense, white, blue):
069.     count = 0
070.     for column in range(8):
071.         if game[column] != -1:
072.             sense.set_pixel(column, game[column], white)
073.             count += 1
074.     if count == 8:
075.         for count in range(3):
076.             time.sleep(0.25)
077.             for column in range(8):
078.                 sense.set_pixel(column, game[column], blue)
079.             time.sleep(0.25)
080.             for column in range(8):
081.                 sense.set_pixel(column, game[column], white)
082.         for column in range(8):
083.             game[column] = -1
084.         return True, False
085.     return False, False
086. def good_move(game, x, y):
087.     if game[x] == y:
088.         return False
089.     game[x] = y
090.     plus, minus = x + y, x - y
091.     for column in range(8):
092.         if column != x:
093.             row = game[column]
094.             if row == y or column + row == plus or column - row
    == minus:
095.                 game[column] = -1
096.     return True
097. def find_best(game, results):
098.     better = 0
099.     best = 0
100.     for count in range(92):
101.         good = 0
102.         for column in range(8):
103.             if results[column][count] == game[column]:
104.                 good +=1
105.         if good > better:
106.             better = good
107.             best = count
108.     return best
109. def find_all(results):
110.     answer  = [0,0,0,0,0,0,0,0]
111.     number, row, count, flag= 0, 0, 8, True
112.     while number < 92:
113.         if flag:
114.             row += 1
115.         flag = True
116.         last = row - 1
117.         answer[last] += 1
118.         if row == 1:
119.             answer[last] = count
120.             count -= 1
121.         if not answer[last]:
122.             break
123.         if answer[last] > 8:
124.             answer[last] = 0
125.             row -= 1
126.             flag = False
127.         if flag and row != 1:
128.             flag = test(last, row, answer)
129.         if flag and row == 8:
130.             flag = False
131.             for column in range(8):
132.                 results[column][number] = answer[column] - 1
133.             number += 1
134.     return
```

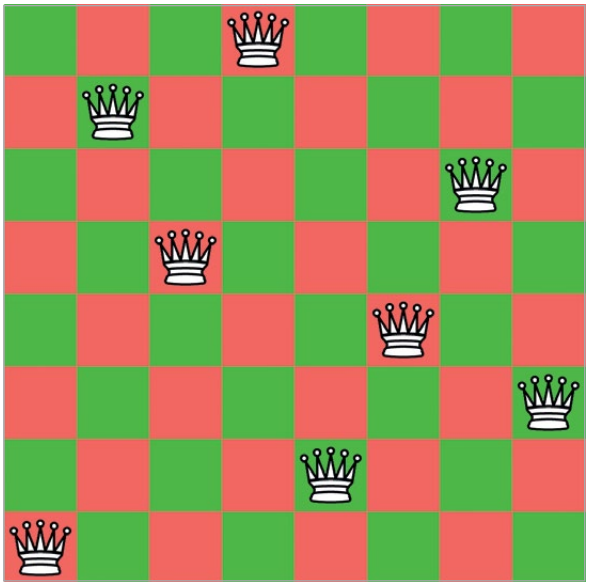


Figure 2 The knight's move can prove useful, but it's not always sufficient to place all eight queens on the board

a clear definition, it's quite challenging to model it in program code. Perhaps using a neural network might be one approach to solving this problem and maybe, one day, this puzzle could be a suitable task for a quantum computer, but for today we'll look at how a straightforward Python program running on a Raspberry Pi can play eight queens and show us where we're going wrong if we get stuck.

Let's take another look at the eight queens in **Figure 2**. Only eight of the 64 squares are occupied by queens and most of the board is empty. There's just one queen in every column and one queen in every row. Every solution to the eight queens puzzle has only one queen in every column and row and so we can represent the 2D chessboard in **Figure 2** much more efficiently as a one-dimensional list with eight elements, rather than use a 2D list in which 56 of the 64 elements are empty. We can use the index to our eight-element list to represent the columns of the chessboard, and a number stored in each element to represent the row in which the queen is placed. The 2D LED matrix on the Sense HAT has its origin in the top left-hand corner and so the solution in **Figure 2** could be represented in a one-dimensional list as [7,1,3,0,6,4,2,5]. This reduction of a 2D chessboard to a one-dimensional list is the approach we have taken in our program. Note that board columns and rows are numbered from 0 to 7, not 1 to 8. So the zeroth element in the list stores the number 7 (the queen at the bottom left), and the first element the number 1.

Finding all the possible solutions is now quite simple. All we have to do is make sure that every element of our one-dimensional list has a unique number in the range from 0 to 7 and this will ensure that the queens they represent do not threaten each other either vertically or horizontally. The queens can threaten each other diagonally and so we need to make sure that every number stored in the list does

not present a diagonal threat to any other number stored in the list. This again is quite easy to check. Let's consider the list above which has the number 3 stored in the second element. This means that neither the first nor the third element can be 2 or 4 as this would represent a diagonal challenge to the second element. Similarly neither the zeroth nor the fourth element can be either 1 or 5, and so on for every element in the list. In this way the program eliminates a diagonal challenge to the queens. This reduces the number of possible solutions from 4.5 billion to a much more manageable 92, and the Python program can find all of them very quickly. The program can also determine whether an incomplete solution on which a player gets stuck is part of a complete solution by comparing a player's incomplete solution to all 92 possible solutions. If an incomplete solution is not a subset of a complete solution, then the program finds the closest solution to the incomplete solution and shows the player where they were going wrong.

Let's play eight queens on the Raspberry Pi

The program runs on a Sense HAT or on an online Sense HAT emulator. All user interaction with the program is done using the Sense HAT mini joystick on a real Sense HAT, or the arrow keys and **RETURN** key on an emulator. In the rest of this description we'll assume that a real Sense HAT is being used, but illustrate the puzzle with pictures from an emulator.

When the program starts, you will see a representation of a chessboard with a blue cursor (**Figure 3a**). You can move the cursor onto any empty square with the joystick and then press the joystick button to place a white queen over the cursor (**Figure 3b**). Placing queens like this is the first of three roles for the joystick button. After placing a queen, the cursor can be moved to another empty square and another queen can be placed over the cursor (**Figure 3c**). The program assumes that the latest move is the one you really want to make and if any queens are under threat from the latest move then the threatened queens will be removed from the board. This continues until there are eight queens on the board (**Figure 3d**).

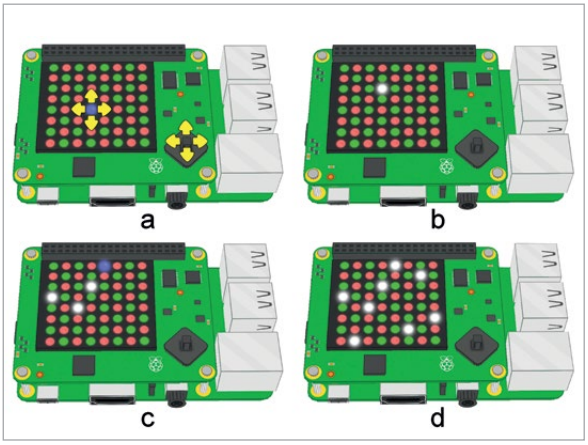


Figure 3 The blue cursor (Figure 3a) is used to find a place for a queen on the board. Move the cursor with the joystick and press the joystick button to place a queen over the cursor (Figure 3b). This cursor will now be hidden by the queen, but it will reappear when it's moved again by the joystick. It can then be moved around the empty squares (Figure 3c). The game is complete when there are eight queens on the board (Figure 3d)

```
135. def test(last, row, answer):
136.     while (last):
137.         column = answer[last -1]
138.         trial = answer[row -1]
139.         if trial == column or trial == (column + row - last) or
     trial== (column - row + last):
140.             return False
141.         last -= 1
142.     return True
143. def increase(square):
144.     if square > 0:
145.         square -= 1
146.     else:
147.         square = 7
148.     return square, True
149. def decrease(square):
150.     if square < 7:
151.         square += 1
152.     else:
153.         square = 0
154.     return square, True
155. if __name__ == '__main__':
156.     main()
```

Figure 4 The incomplete puzzle in Figure 4a can be solved by moving the cursor under one of the queens and pressing the joystick button. The white queens in Figure 4b were placed correctly, the blue queens were in the wrong place, and the yellow queens are the ones you needed to place in order to complete the puzzle

Let's suppose you get stuck and you want the computer to solve the puzzle for you. Move the cursor under any one of the queens already on the board and press the joystick button (**Figure 4a**). Asking for a solution in this way is the second use of the joystick button. The program will display the closest complete solution to your incomplete solution (**Figure 4b**). The white queens in **Figure 4b** represent the queens in your incomplete solution that were in the right place, the blue queens represent where your queens were in the wrong place, and the yellow queens are the ones you needed to place to complete the puzzle. If your incomplete solution is a subset of a complete solution, then there will be no blue queens on the board. If you move the cursor onto an empty square, then you can start another game.

The third and last use of the central joystick button is to exit the program. Whenever there are eight queens on the board, you can move the cursor under a queen and press the joystick button to exit the program. This is much neater than using **CTRL+C** on the keyboard and it keeps all the interaction with the game on the Sense HAT joystick.

LAURA SACHS

Laura creates and maintains Raspberry Pi educational resources. Aside from computers, she loves cats, cakes, board games, and making jam.
raspberrypi.org

JAZZY JUMPERS MEMORY GAME

Create a memory game in Scratch where you need to remember the patterns of some Christmas jumpers

You'll Need

- Scratch 2.0
- Offline assets (optional) **magpi.cc/2ATrxyb**

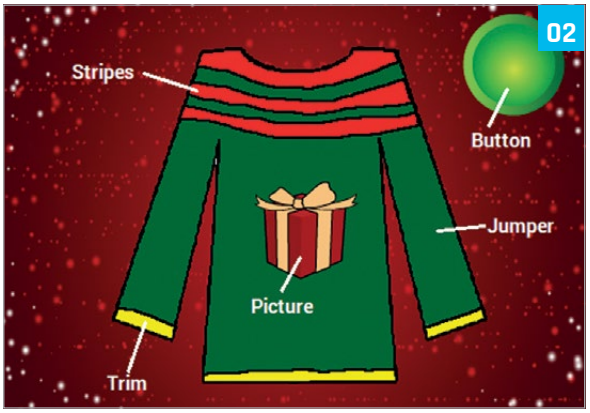
Memory games are quite fun and, as it turns out, simple to make in Scratch. In this game you need to memorise the jazzy jumper, then click on each part of the jumper template you're shown to change the colours and recreate the jumper you've memorised. When you think you've got it, press the button to see if you were right or not.

Parts of the jumper

Open the starter project online (**magpi.cc/2ihuixR**) or use the offline starter project (**magpi.cc/2ATrxyb**).

If you are using Scratch online and you have a Scratch account, click on Remix in the top right-hand corner to save a copy of the project to your account.

Take a look at the sprites in the project. You have five sprites in total: one for each of the four parts which make up the jumper, and one for the button. (See **Figures 01** and **02**.)



Click on the Jumper sprite and then on the Costumes tab. You will see three coloured costumes and a white 'none' costume (see **Figure 03**)

If you like, you can use the Fill tool to change the colours of the costumes. Change the names of the costumes too, so that they match the new colours. However, make sure to leave the 'none' costume at the bottom, and make sure it remains completely white. This costume is shown when the player is trying to remember the jumper.

If you want to, you can change the colours or pictures of all four sprites which make up the jumper: Jumper, Stripes, Trim, and Picture.

New jumper

In this project there are a lot of sprites, and a good way of telling lots of sprites what to do is to send a broadcast.

Let's create a broadcast which tells the various sprites forming the jumper to each choose a random costume, so that they form a new jumper.

Click on the Stage and make sure you are on the Scripts tab. The Stage is going to send a broadcast called **`new jumper`** to all of the other sprites. Think of this like a person with a megaphone giving instructions to lots of people at once. Add the code blocks from **Figure 04** to the Stage scripts area.

Now we need to let the sprites know what to do during this broadcast. Click on the Jumper sprite in the Sprites panel. Add the block in **Figure 05** to the scripts for the Jumper sprite.

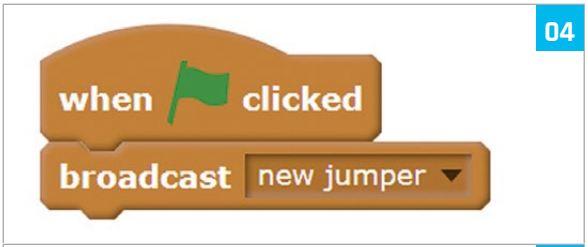
You can tell the Jumper sprite exactly what to do when it hears the broadcast by attaching the blocks you want to happen below this block.

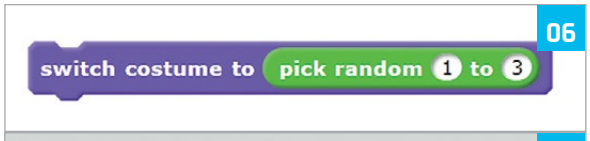
When the Jumper sprite hears the broadcast, it should randomly pick one of the coloured costumes – but not the white one.

Attach some code to your **`when I receive`** block to tell the Jumper sprite to pick a random costume out of the first three only (**Figure 06**).

Click the green flag. Does the Jumper sprite colour change? Click the green flag a few more times to check.

The colour might not change every single time you click the green flag, because sometimes the randomly chosen costume will be the same as the previous one. Now add some code to the Stripes, Picture, and Trim sprites so that, when they hear the broadcast **`new jumper`**, they also choose a random costume. (Hint: just use the same code as the Jumper sprite.)





Hide the jumper

The aim of the game is for the player to memorise the jumper, so you need to make it disappear after a few seconds.

Go back to the Stage and add some code so that, when the Stage receives the **`new jumper`** broadcast, it waits for three seconds and then broadcasts a new **`hide jumper`** message (**Figure 07**)

Switch to the Jumper sprite. Add some code so that, when this sprite hears the **`hide jumper`** broadcast, it switches to the blank 'none' costume (**Figure 08**).

Add similar code to the other sprites making up the jumper. Click the green flag and test your code. Does the Jumper switch to all white with a question mark picture, three seconds after the green flag is clicked?

What was on the jumper?

So far, the program creates a random jumper for the player to remember, and then hides it. However, we've made a mistake! We didn't note down anywhere which costumes were randomly chosen, so how will we know if the player has recreated the jumper correctly?

To save information you will need to use later on, you can create variables. Click on the Jumper sprite, then the Data block type, and create a variable called **`jumper`**.

You're going to save the random costume that was chosen for the Jumper sprite inside this variable, so the program remembers it for later.

Place a **`set jumper`** block between the **`when I receive new jumper`** and **`switch costume`** blocks. We need to set the **`jumper`** variable to **`pick random 1 to 3`**, so just drag that green block up to **`set jumper`** from the **`switch costume`** block below. Finally, alter the **`switch costume`** block to set it to the value of the **`jumper`** variable, which now holds a random number between 1 and 3 (**Figure 09**, overleaf).

Click the green flag and check that your Jumper sprite still chooses a random colour each time.

Create three more variables, one named after each other sprite making up the jumper. Add some code to the other three sprites so that their costume number is saved in the variable named after it. Your code will be slightly different for each sprite, because each sprite will have its own variable.

Make sure that you hide the variables from the stage by right-clicking them and selecting **hide** (**Figure 10**), otherwise the game will be too easy for your player!

Recreate the jumper

The player needs to be able to recreate the jumper they saw by clicking on the different parts until they match the original one.

Switch to the Jumper sprite and add some code so that, when the sprite is clicked on, it will display the next available costume (**Figure 11**).

Add the same code to the other three sprites making up the Christmas jumper.

Test your code by waiting for the blank jumper to display, and then clicking on the different parts. Do they change colour each time you click?

HINT: if you accidentally drag the Jumper sprite, it'll come to the front and obscure the other sprites – to prevent this, you can add a **go back 3 layers** block under its **next costume** block.

The right jumper

When the player thinks they have recreated the jumper correctly, they should click on the button to be told whether they were right or wrong.

Click on the Button sprite and take a look at its costumes (**Figure 12**).

The 'right' and 'wrong' costumes will be used to display whether the player's jumper was the same as the one that was displayed at the start.

Add some code to the Button sprite so that, when it is clicked, it broadcasts a new message called **check** (see **Figure 13**).

When the other sprites hear the message **check**, they should each check whether the current costume number is the same as the costume number saved in the variable named after them. If the costume numbers do not match, the sprites should broadcast the message **wrong**.

Switch to the Jumper sprite and add some code to check whether the player selected the correct colour. If they were wrong, broadcast **wrong** (**Figure 14**).

Note that you will need two green Operators blocks: one for **not**, and another one inside it for **=**.

Add similar code to the other three sprites making up the jumper, but be careful to check the current costume number against the correct variable for that sprite. Now switch back to the Button sprite.

We will assume the player is right unless we receive a broadcast saying they were wrong. Add a block after you broadcast **check** to switch to the 'right' costume (see **Figure 15**).

Also add blocks to switch to the 'wrong' costume if the **wrong** broadcast is received (**Figure 16**).

If any of the sprites making up the jumper broadcasts that its costume was wrong, the player will see the **X**. If not, they will see the ✔.

Note that if you click the green flag again to restart, the Button sprite will stay as an **X** or ✔, so you may want to add some code to switch its costume to 'button' when the green flag is clicked.

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BRIAN BEUKEN

Very old game programmer now teaching very young game programmers a lot of bad habits at Breda University of Applied Science in the Netherlands.
scratchpadgames.net

CODING GAMES ON THE RASPBERRY PI IN C/C++ PART 01

You'll Need

- Code::Blocks
- Some imagination
- A bit of patience

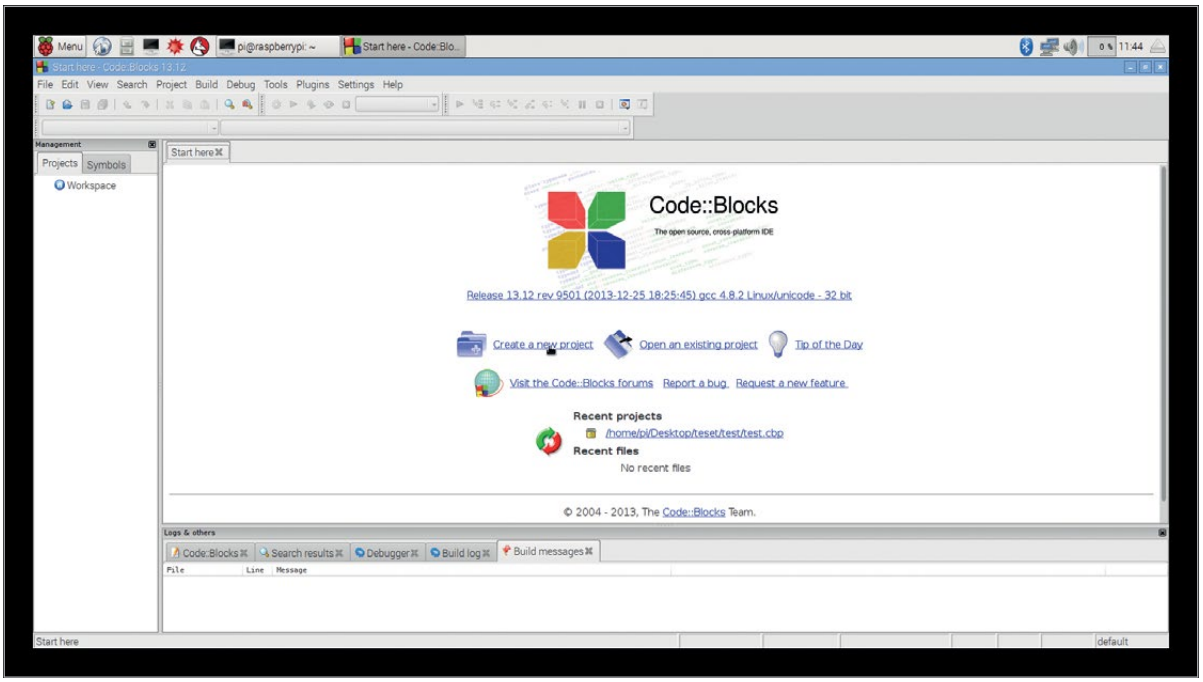
Let's dive into a subject that many people think is actually much harder than it is: game programming on the Raspberry Pi!

Despite its awesome success as a hobby system, the Raspberry Pi is seldom looked on as a machine that lets you write or play your own graphical games. There are emulators, of course, and those are a great introduction to the style of retro games most old-school coders cut their teeth on as spotty youths. However, you don't see many original games written for the Pi, on the Pi, by Pi coders. Let's try to change that.

Game coding, on Raspberry Pi, in a professional language like C/C++ isn't apparently very popular, but why? The Pi is more than capable of doing cool graphics, has (nearly) all the tools needed on board, and just enough horsepower to easily create and run high-octane 2D games. It can even push a decent amount of polys around to create some quite exciting 3D experiences.

There's simply no reason not to write cool games on the Pi, so it's time we addressed this and introduce some new Pi coders to C++ and game coding, as well as a little dabble with the Broadcom GPU.

Over the next few issues, we'll outline a 2D game framework which you can explore and enhance to produce a range of 2D games.


Code::Blocks
The open source, cross-platform IDE
Release 13.12 rev 9501 (2013-12-25 18:25:45) gcc 4.8.2 Linux/unicode - 32 bit
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Open an existing project
Tip of the Day
Visit the Code::Blocks forums
Report a bug
Request a new feature
Recent projects
/home/pi/Desktop/teset/test/test.cbp
Recent files
No recent files
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Figure 1 The Code::Blocks IDE lets you create a startup console C++ Hello World program

Language
>C++

NAME:
main.cpp, SimpleObj.h/cpp, Game.h/cpp

DOWNLOAD:
magpi.cc/2jyod09

Let's start with the first thing all new coders need to know, which is: DON'T PANIC! C/C++ isn't as hard as people tend to think it is, especially if we stick to core principles and concepts. It can get very complex very fast, but you can take your time and make progress at your own rate and still create cool things.

But before we can use the language, we really need to have a development system known as an integrated development environment, or IDE for short; this contains all our code and lets us edit, build, and debug our code in one program. Of course, you can use multiple files and command-line systems, but IDEs are designed to make things easier, so let's just use them.

For this set of tutorials we're going to use Code::Blocks, which you can find using **`sudo apt-get codeblocks`** in your Terminal window.

Code::Blocks gives us access to a much more C++ friendly editor, compiler and debugger, and lets us run our code directly from the edit screen. Once installed, it appears in Programming tools (**Figure 1**).

First steps

Coders always start learning with the Hello World example, so we should do the same just to get used to our system.

Setting up a new project as a C++ Console App will produce a very simple single-file project. You can find the **main.cpp** file in the Sources filter on the left of your IDE screen; open up Sources and double-click on **main.cpp** to have a look at the file – it's only ten lines long.

Main.cpp should be fairly understandable to a novice. There is a function, called **`main`**, and between its **{** and **}** brackets are two lines of code, one of which outputs some text; the other tells the function to return to where it was called, in this case from the command line, ending the program. The **`using namespace`** will be explained later, but it's a way for C++ to understand that the **`cout`** function, used to print text, lives in its 'internal' standard libraries.

To make the program run we have two options: the green RUN arrow, or the Red Debug Arrow at the top of the Code::Blocks window. Press one; whichever you choose, you will find our project unsurprisingly prints 'Hello World' in what is called a console window, the black screen which pops up when our project starts. The console is very useful since it can allow us to output text to it and let us know what our project is doing at different points.

Alter the **`"Hello World"`** text in the **main.cpp**, so long as the text is enclosed in **`" "`** marks, you can pretty much enter anything you like, you can even repeat the line a few times to add a few more choice text quips. Go on, make it swear at someone, you know you want to.

> "The first thing all new coders need to know: DON'T PANIC! C/C++ isn't too hard"

Now that we have our project running, let's see what Code::Blocks lets us do. Try left-clicking just after the number 7 on line 7 – a small red dot should appear (**Figure 2**); you can also right-click to get more choices. This red dot represents a break point: when our code is being debugged, it will stop. Run the project again, but using the red DEBUG arrow, which will force our project to compile and run in

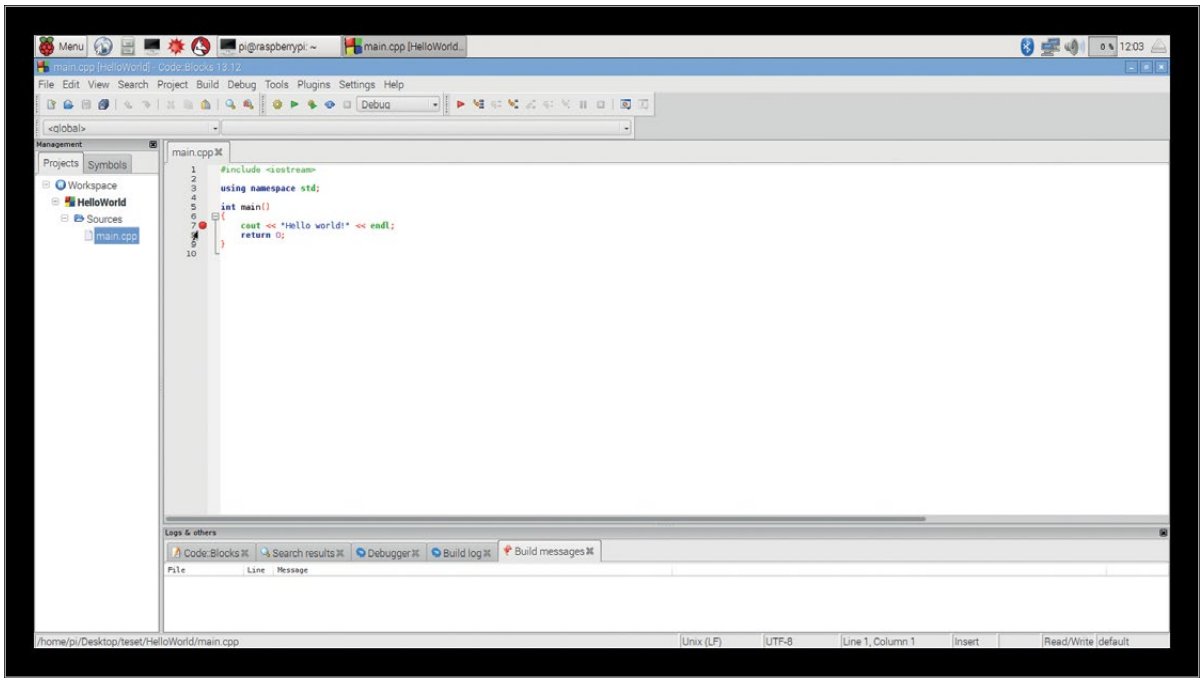

Figure 2
Setting a breakpoint stops the project at that point

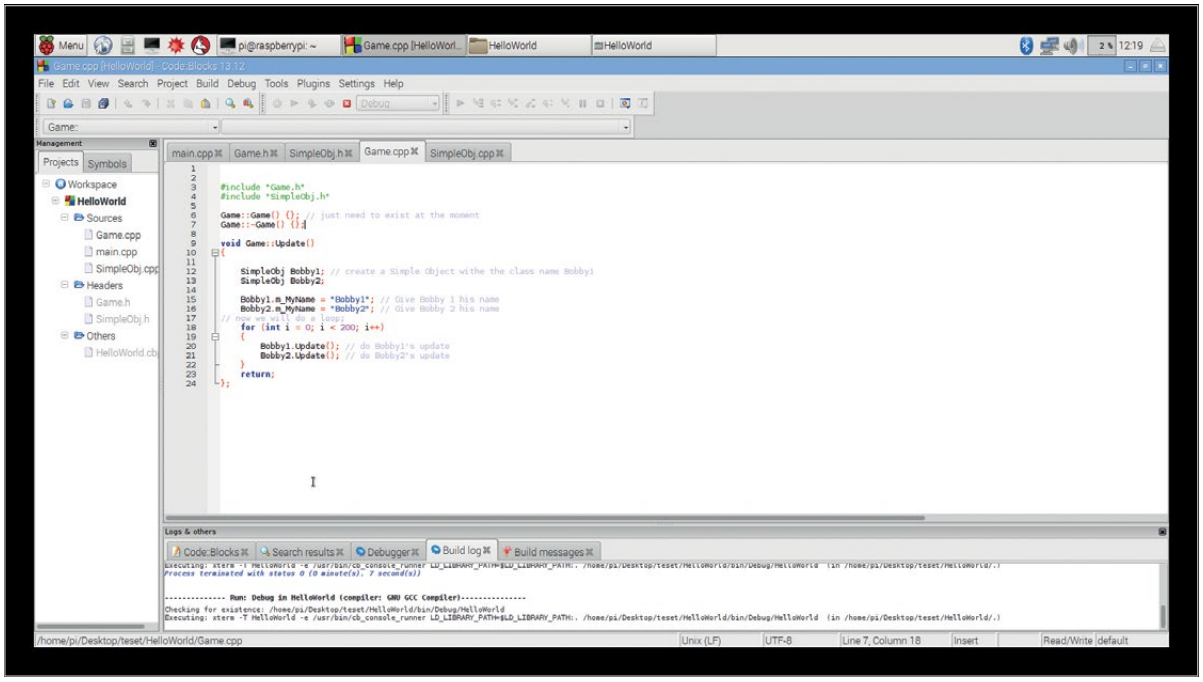

Figure 3
Our `Game` class creates two `SimpleObj`s which get updated

debug mode. It will stop at the red dot, waiting for us to tell it to either continue or to step through the code using the icons next to the red arrow, which provide different step options for the code. More on that later, though. Code::Blocks gives a wide range of tools and functions to help us debug, but if this is your first time running it, not all of them will be visible – we will make them visible as our needs and experience increase.

Time for bigger steps

So, 'Hello World' is hardly the pinnacle of coding, but you've compiled and run your first project; it's text only, but it's our text and we love it. We might not be doing much, but we do know our tools work. Time to take things up a notch.

C/C++ works by using code it already has, known as the standard libraries, and code that you write to make use of those libraries. There are other libraries we can use or even create ourselves, but one important thing to consider is that the **`main()`** function is the starting point of any C/C++ project.

> One important thing to consider is that the main() function is the starting point of any C/C++ project

We could add hundreds of lines of code to our **`main()`** function to make it do something, but that's not really how C++ works. In fact, that's more how C works, because this **`main`** function is in fact a small bit of C code, which brings us to why we persist in saying C/C++.

C++ is an enhancement to C, but inside C++ there are still all the original C commands and concepts which we are free to use if we want to; it's just that as C++ has become more and more stable and effective, we seldom rely on pure C any more, except to start up our project.

C++ can mimic C all day long, but it would deny us the chance to make use of C++'s greatest trick: OOP, or object-oriented programming.

What is OOP?

OOP can be tricky to grasp straight away, but it's best to think of it as a means to define a 'thing' that does 'something', at the request of other 'things'.

We usually call these things *objects*, and we define them in concepts called *classes*. A class is C++'s way of describing something as a collection of functions and data which are usually personal to any individual instance of that class. Objects can be literally anything, and such a broad idea is where people tend to get stuck.

We can create things, or classes, using a simple header file to define that class. We should start with a base class called **`Game`**, which is going to be our controlling class. We can let the **`main()`** function do a little setting up, but the sooner we leave it behind the better.

Our **`Game`** class will be responsible for controlling all the other objects in our project, some of which will themselves have objects to control. But **`Game`** is the big cheese and its job is going to be to create and initialise the objects, control the calling of updates of those objects, and then to output or return the results of their efforts somewhere. Finally, when our project has run its course, it needs to return back to the **`main`** function, to let the program shut down.

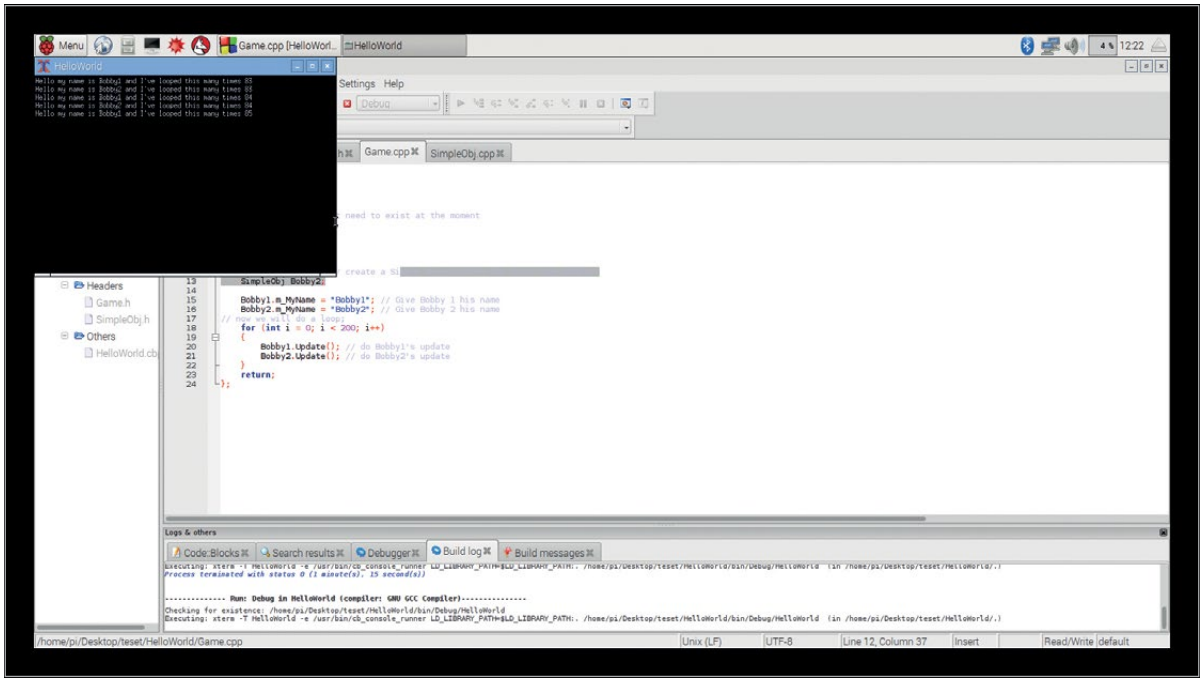

Figure 4
And our two different objects now output some simple text

That's a lot to take in, so let's just try a simple bit of code to see how that works.

Starting with C++

Almost all classes have a header file that's unique to the class; check out **Game.h**, in our GitHub repo.

We've defined the **Game** class as having three methods, two of which are standard, and one is something we will use to update all the systems it has.

If we now look at how our new **main** function sets up a **Game** class, seen in **main.cpp**, just replace all the old code that was in Hello World.

Main() now has an instance of a **Game** class; we use a special function called a constructor to set up some default variables, or not, as needed. Once **main()** creates a **Game** class, we then effectively pass the program control to **Game** and its **Update()** method – we'll only return to **main()** when we are done and want to exit back to the OS. Of course, at the moment, the actual code for **Game** has not been written; let's discuss that next.

Now that our **main** function has passed control of our program to **Game**, it's up to **Game** to give us some 'things' to play with. Let's create some simple objects, called **SimpleObj**. Like the **Game** class, we define these in a header file, preferably using the same name as the class we define, **Game.h**.

Ready to run

These are just definitions at the moment; the header contains info on what the class is and what it contains. This **SimpleObj** has very little code; it has the constructor/destructor methods, which we'll discuss next time. More useful is the fact it also has a method called **Update()** and a function called **Draw()**, which currently does nothing; we'll add that soon. It has some variables, notably a string called **m_MyName**, but that's empty when it is first created.

Now that we have the definition of a **SimpleObj** class, we need to write the actual code, this time not in a header but in a CPP file. So, create a file called **SimpleObj.cpp** and then the **Game.cpp** file (**Figure 3**) and enter the code from the file in our GitHub repo – you could download this code, but it's better if you type it in and get used to making and fixing typos.

So far so good

We have code for **Game** and **SimpleObj**, so we should be able to compile this on our IDE. When next we run the code, **Game** has two new instances of **SimpleObj** – they're rather boring and dull, but they are there, and we include calls to their **update()** functions in the **Game** class's main loop. They will be processed and print out little individual messages using their names to let you know they are there (**Figure 4**).

So, two unique instances of **SimpleObj** are being updated by **Game.Update()**, both defined by the same class definition, but unique instances with their own names. Try adding a third and see what happens.

For now, that's as much as we can squeeze into this format, but next time we will expand our code to start working with graphics and the famous 'hello triangle' code that absolutely no one uses except game coders.

LEARN TO CODE WITH C

Enjoying using C and C++ and can't wait until next month for more? Check out our Essentials book, *Learn to Code with C*, for more C tutorials for beginners: **magpi.cc/learn-c-book**

FREQUENTLY ASKED QUESTIONS

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PORTABLE PI POWER

WHAT PORTABLE POWER OPTIONS ARE AVAILABLE?

Mobile battery

One of the easiest ways to portably power a Raspberry Pi is to use a standard mobile phone battery charger. The Raspberry Pi isn't all that power hungry, so it should last a while on even a lower-capacity battery, but make sure it's capable of providing at least 2A of power

Battery pack

Normal AA batteries and the like can't just be plugged into a Raspberry Pi. With the right HAT or adapter cable, however, you can use them to power a Pi. The adapters and HATs make sure the power output is consistent, as normal batteries have a habit of not working well on a low charge.

Lithium batteries

Adafruit does an excellent range of power adapter (and charger) boards that allow you to power a Raspberry Pi with a lithium-ion battery (**magpi.cc/2AddAex**). While a little more tricky to set up than a mobile charger or battery pack, the combo is small and can easily slip into your Pi project.

WHAT POWER CONSIDERATIONS ARE THERE?

Amps

One of the most important things to think about when deciding on portable power options is making sure your solution can supply enough power to the Raspberry Pi. 2.5A is recommended for making full use of a Raspberry Pi 3. If you're not using the desktop or any extra add-ons, however, you can get away with a slightly lower 2A supply.

Charge

Battery charge is measured in mAh (milliampere hours). High-capacity mobile phone battery chargers tend to come as high as 20 000 mAh. These can charge your phones from empty about four to five times over, depending on your device, and will provide power to a Raspberry Pi for a very long time – we've heard reports of days. You will need to experiment to figure out how much you'll need, though.

Size

Not all projects are built the same, so the size of your power supply is an important factor. Smaller solutions will also naturally have less charge, meaning you'll have to swap them or charge them more regularly.

WHAT PI POWER PORTS CAN I USE?

Micro USB

The most common way to power the Raspberry Pi is via the standard micro USB power port. All three of the main solutions we've highlighted will have ways of connecting via USB to power the Pi, although it does mean one extra cable in your setup.

GPIO

A more compact way of powering the Pi is via the GPIO pins. Some HAT mobile power solutions power the Pi via the GPIO, like the PiJuice HAT (**magpi.cc/2B3WPlP**). You need to be very careful with the power going to the GPIO pins, though – it needs to be consistent or you risk burning out the GPIO or even the Pi!

USB pads

A bit riskier, but you can always solder the individual wires of a USB cable to the connectors on the board. This allows you to save some space from the relatively bulky micro USB adapter. You need to be fairly confident with your soldering skills, though, or the wires may break loose at an inopportune moment.

FROM THE RASPBERRY PI FAQ
RASPBERRYPI.ORG/HELP

WHAT IS THE CAMERA MODULE?

The Camera Module is a small PCB that connects to the CSI-2 camera port on the Raspberry Pi using a short ribbon cable. It provides connectivity for a camera capable of capturing still images or video recordings. The camera connects to the Image System Pipeline (ISP) in the Raspberry Pi's SoC, where the incoming camera data is processed and eventually converted to an image or video on the SD card (or other storage). You can read more about the Camera Module at **magpi.cc/28ljlsz**.

WHAT IMAGE SENSOR DOES THE CAMERA MODULE USE?

The Camera Module V2 uses a Sony IMX219, while the original Camera Module has an Omnivision OV5647. They are comparable to cameras used in mobile phones.

WHAT RESOLUTIONS ARE SUPPORTED?

The Camera Module V2 is capable of taking photos up to 8 megapixels (8MP). It supports 1080p30, 720p60, and VGA90 video modes, as well as still capture. The original Camera Module is capable of taking photos up to 5 megapixels and can record video at resolutions up to 1080p30.

WHICH PICTURE FORMATS ARE SUPPORTED?

The Raspberry Pi Camera Module supports raw capturing (Bayer data direct from the sensor) or encoding as JPEG, PNG, GIF and BMP, uncompressed YUV, and uncompressed RGB photos. It can record video as H.264, baseline, main, and high-profile formats.

HOW DO I USE THE CAMERA?

There a number of command-line applications provided for stills and video output. These applications provide the typical features you might find on a compact camera, such as setting the image size, compression quality, exposure mode, and ISO. See the documentation for more details: **magpi.cc/2egdAQA.**

CAN I EXTEND THE RIBBON CABLE?

Yes. We have reports of people using cables up to 4 metres in length and still receiving acceptable images, although your experience may differ.

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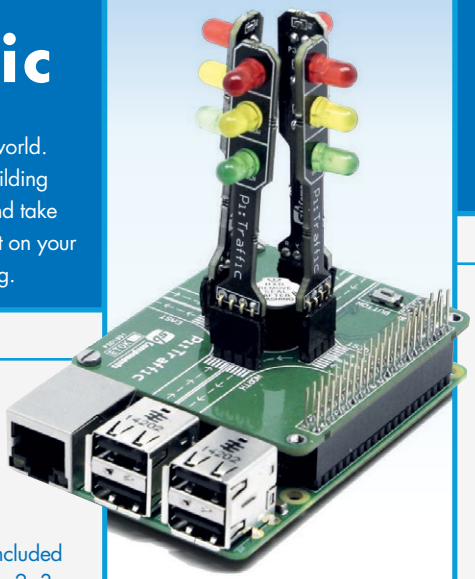

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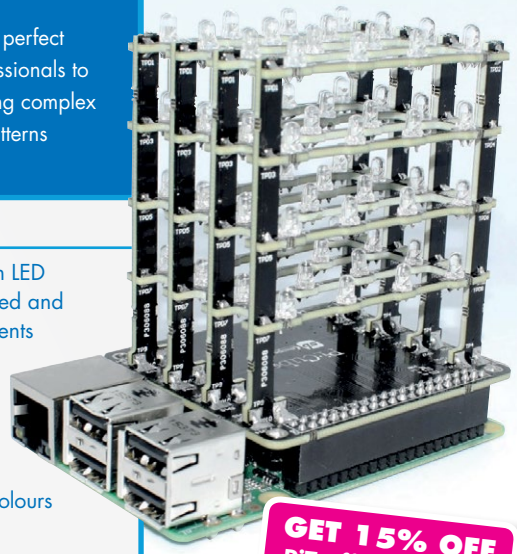
- Available in three vibrant colours RED, GREEN, BLUE
- Comes un assembled and fully assembled



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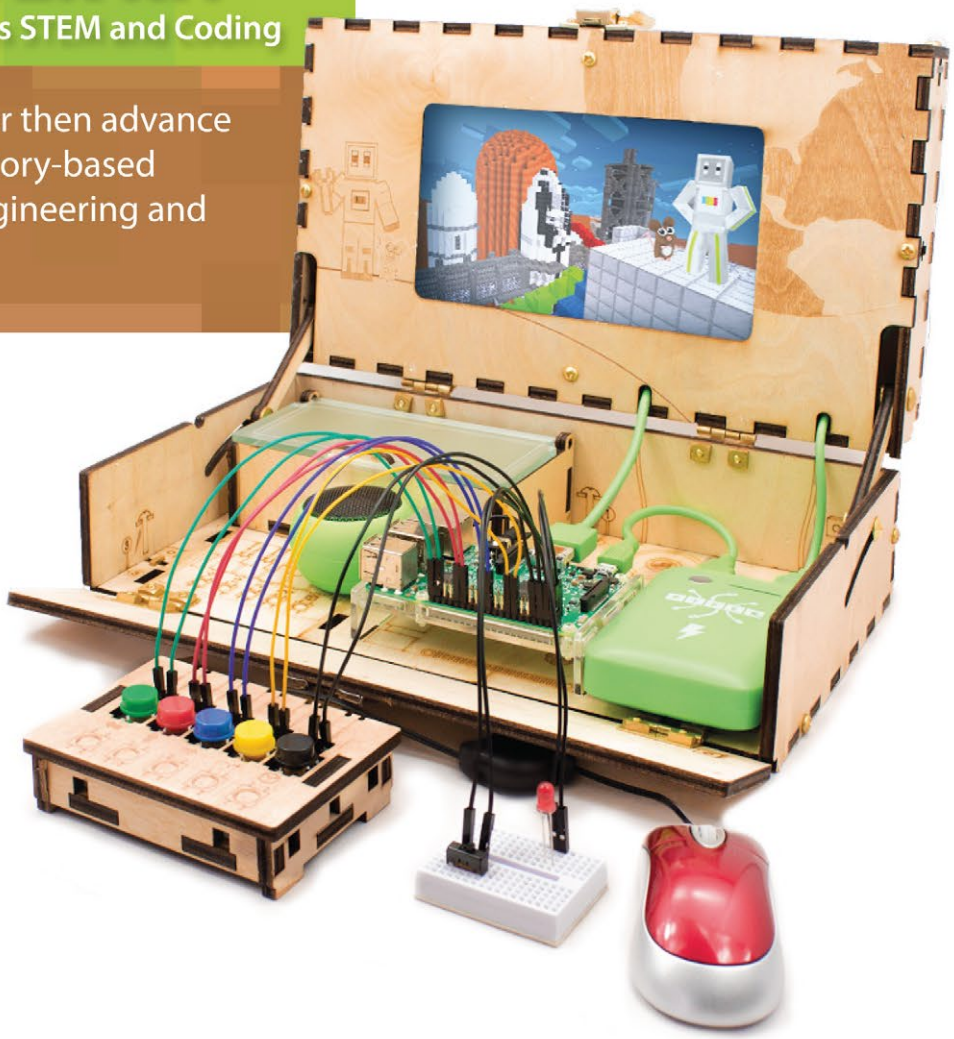

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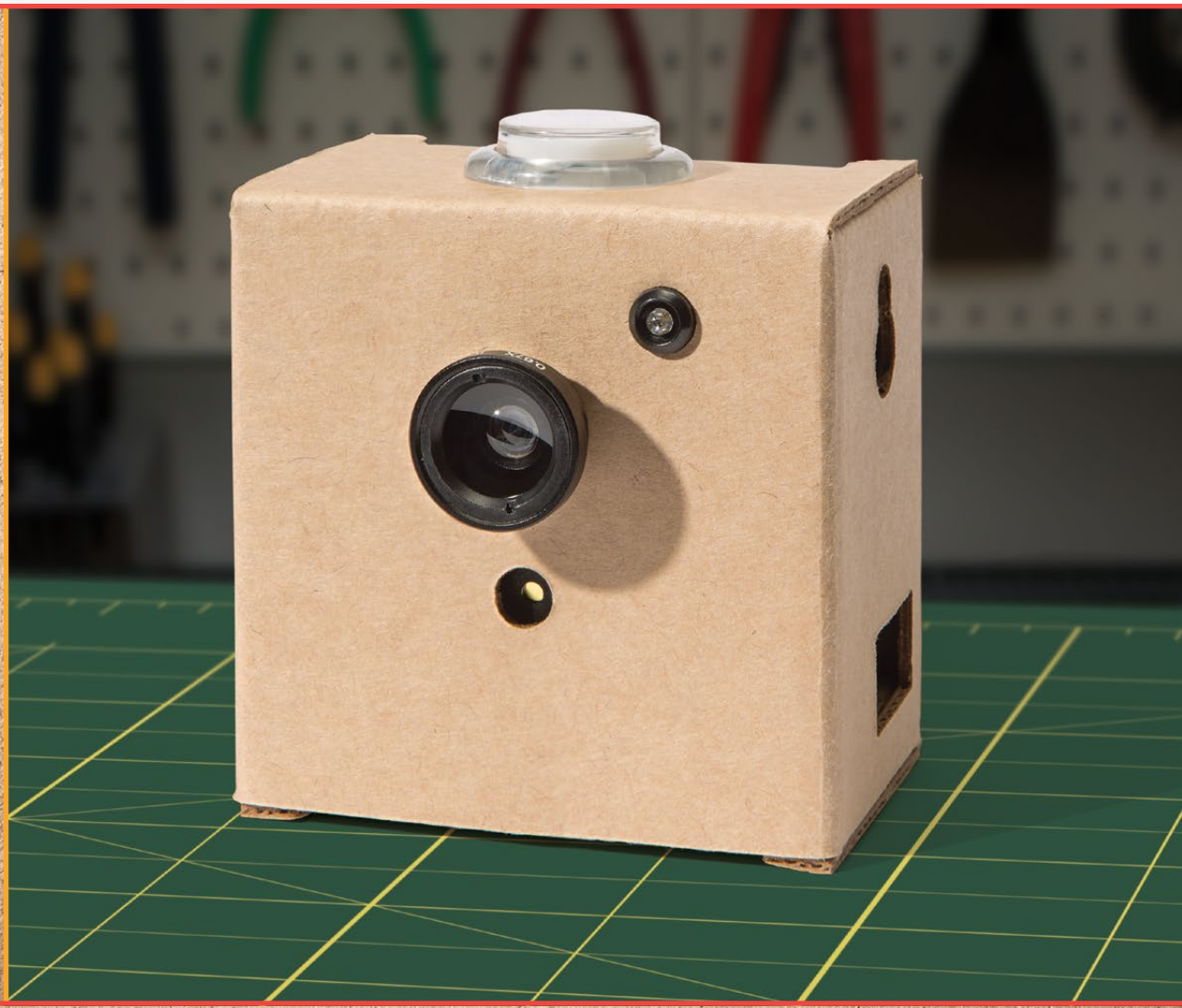
AIY

INSIDE THE VISION KIT

Add vision intelligence to your Raspberry Pi projects with Google's new VisionBonnet



Last month, we broke the news of Google's all-new Vision Kit. This new AIY kit enables you to build an intelligent camera using a Pi Zero W and Camera Module.

Of course, this being AIY, you can also use the hardware to add artificial intelligence to your own projects.

The kit's powerful VisionBonnet coupled with a Pi Camera doesn't just capture images of objects, it also identifies them.

The Vision Kit is powered using TensorFlow's (**tensorflow.org**) machine learning models and can be trained to detect all kinds of things: cats, dogs, humans, household objects, even emotions such as smiling or frowning.

> "We want to lift some of the magic away from AI"

This month, we're taking a closer look at the AIY Projects: Vision Kit hardware, software, and the possibilities it offers for integrating artificial intelligence with your projects.

We're also going to look at the underlying techniques being used in artificial intelligence: artificial neurons and neural networks. We want to lift some of the magic away from AI and help you turn it into a tool for your project-making toolbox (albeit an incredibly cutting-edge tool).

As with all AIY Projects, what's really interesting is how you can integrate Google's artificial intelligence into your projects.

So be sure to get some inspiration for your projects, and share with us what you plan to make with Vision Kit.

HELPFUL TERMS

ARTIFICIAL INTELLIGENCE
Intelligence displayed by machines, in contrast with biological intelligence – the 'Y' in AIY stands for 'Yourself'.

ARTIFICIAL NEURON (AKA 'PERCEPTRON')
A software function designed to mimic the behaviour of a neuron.

COMPUTER VISION
An application that analyses an image (or sequence of images) and extracts useful information.

CONVOLUTIONAL NEURAL NETWORK
A type of artificial neural network designed specifically for analysing visual imagery.

DEEP LEARNING
A subset of machine learning which is based on learning data representations (instead of task-specific algorithms).

IMAGE CLASSIFICATION
Taking an input image and inferring a class, such as a 'cat', 'dog', or 'human'.

INFERENCE
A probable conclusion reached on the basis of evidence and reasoning. The Vision Kit may take a look at an image of a cat, for example, and infer that the image contains… a cat.

MACHINE LEARNING
The field of computer science that gives computers the ability to learn without being explicitly programmed for tasks.

MACHINE INTELLIGENCE
Artificial intelligence displayed by machines, as opposed to natural intelligence (displayed by humans). Typically used when AI is coupled with hardware.

MACHINE VISION
The technology and methods used to provide imaging-based automatic inspection and analysis.

NEURAL NETWORK
A connected system (built from connected nodes/neurons of data). Inspired by the biological neural networks that constitute animal brains.

NEURON
A biological cell that carries an electrical impulse. The human brain contains roughly 100 billion neurons.

NODE
A basic unit used in computer science. Typically it's a single value, cluster of values, or function. Nodes are typically arranged into connected structures called graphs (or 'binary trees'). In a neural network, the artificial neurons are connected together as nodes in a graph structure.

OBJECT RECOGNITION
Technology in the field of computer vision for finding and identifying objects.

See Wikipedia's Glossary of Artificial Intelligence for more information: **magpi.cc/2joDjjo**

INSIDE THE AIY PROJECTS VISION KIT

Setting up your AIY Projects Vision kit

When you first get hold of your Vision Kit, you'll use it to set up a Smart Camera. This cardboard box has a camera lens, button, LED light, piezo buzzer, and a Privacy LED (so you can see when it's recording).

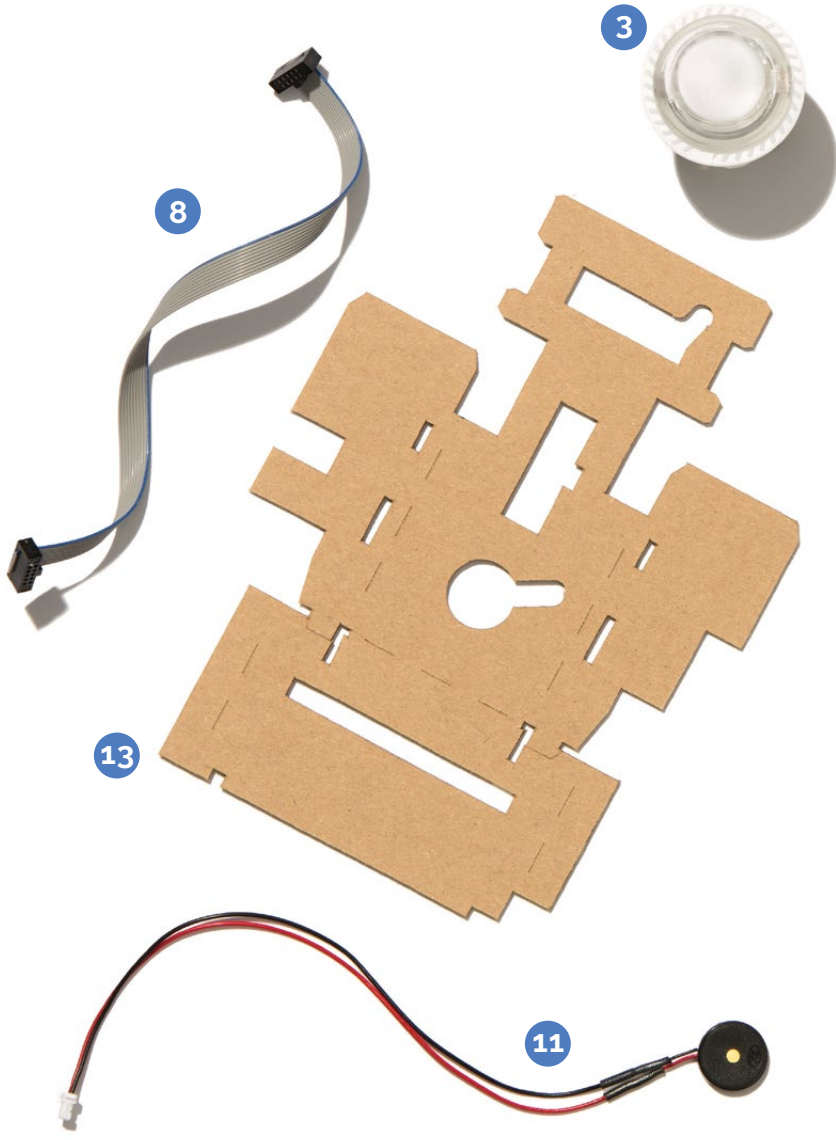
All you need is a Raspberry Pi Zero W, a Pi Camera Module V2, and a blank microSD card. A free Android app is coming soon to help you easily control your device.

You will need a Pi Zero W with a GPIO pin header attached. You can solder the pins to your Pi Zero W, or buy a pre-soldered Pi Zero W, such as this model from Pi Supply (**magpi.cc/2BKwDsD**).

You'll need to download the Vision Kit SD image (available from the AIY Projects website, **aiyprojects.withgoogle.com**) and write it to the microSD card.

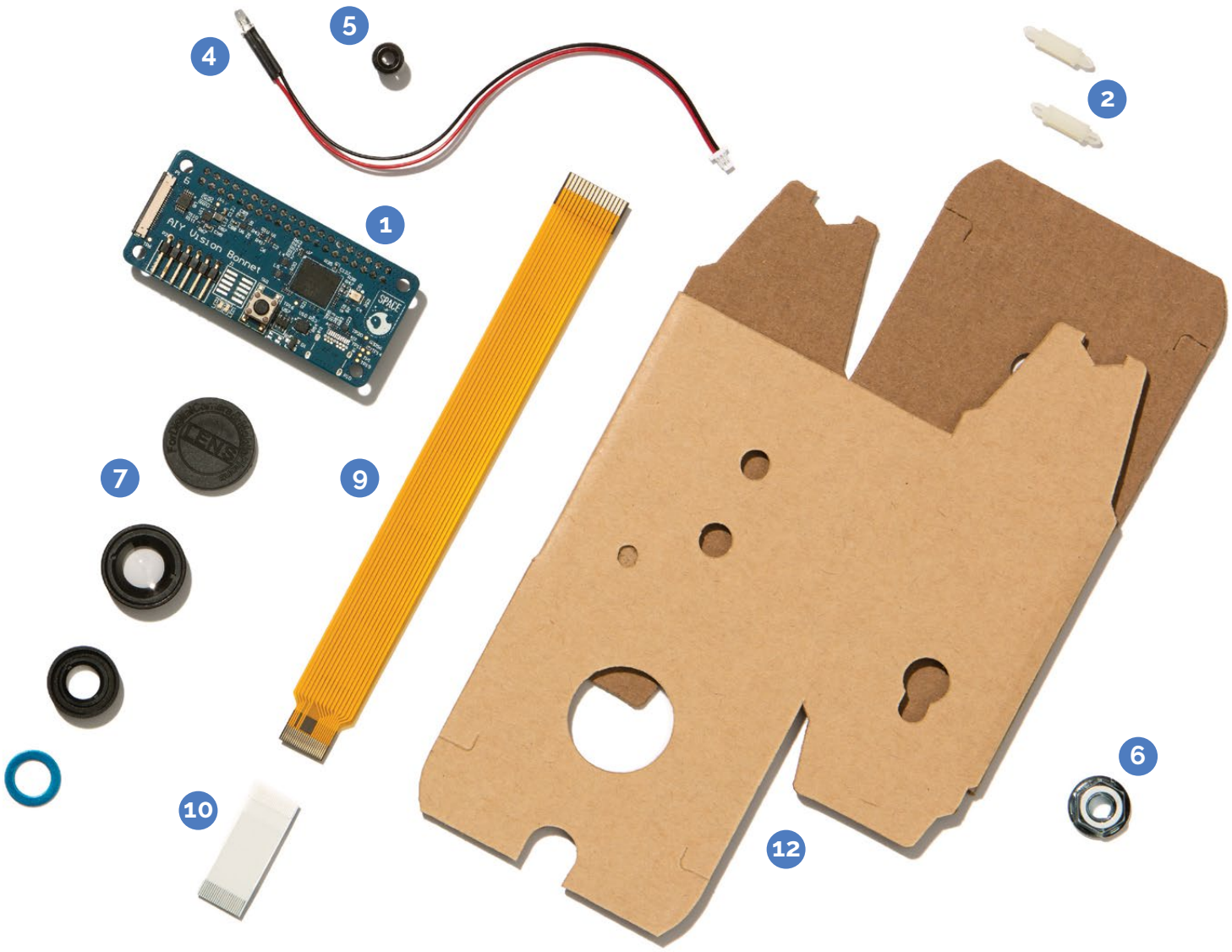
After it's downloaded, write the image to your microSD card using a card-writing utility such as Etcher.io (see Burn SD Cards with Etcher, **magpi.cc/2fZkyJD**).

While downloading the Vision Kit SD image, you can assemble the Vision Kit cardboard case. We have some truncated steps overleaf, showing how the parts of the kit work together – the full step-by-step guide can be found on the AIY Projects website.



INSIDE THE VISION KIT

1. VisionBonnet accessory board (×1)
2. 11 mm plastic standoffs (×2)
3. 24 mm RGB arcade button and nut (×1)
4. Privacy LED (×1)
5. LED bezel (×1)
6. ¼″-20 flanged nut (×1)
7. Lens, lens washer, and lens magnet (×1)
8. 1.27mm ribbon cable (×1)
9. Pi Zero camera flat flex cable (×1)
10. MIPI flat flex cable (×1)
11. Piezo buzzer (×1)
12. External cardboard box (×1)
13. Internal cardboard frame



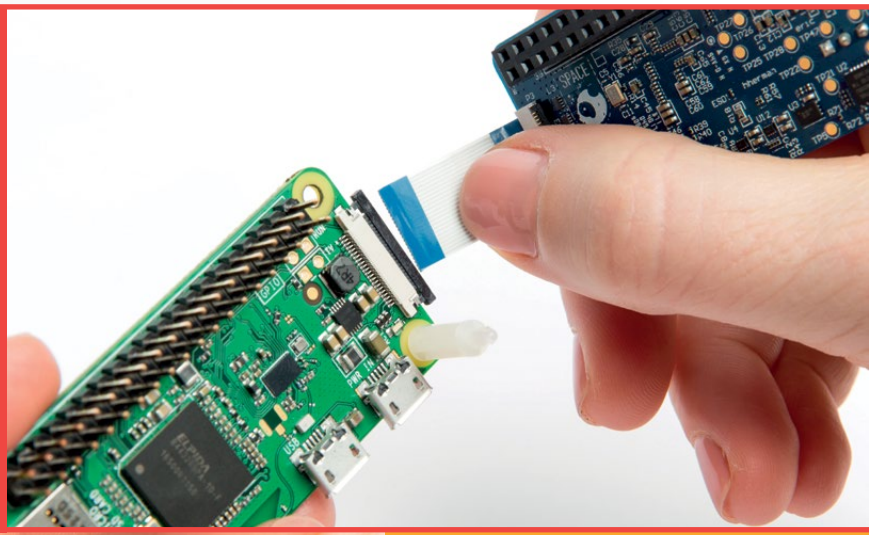
HOW THE PARTS FIT TOGETHER

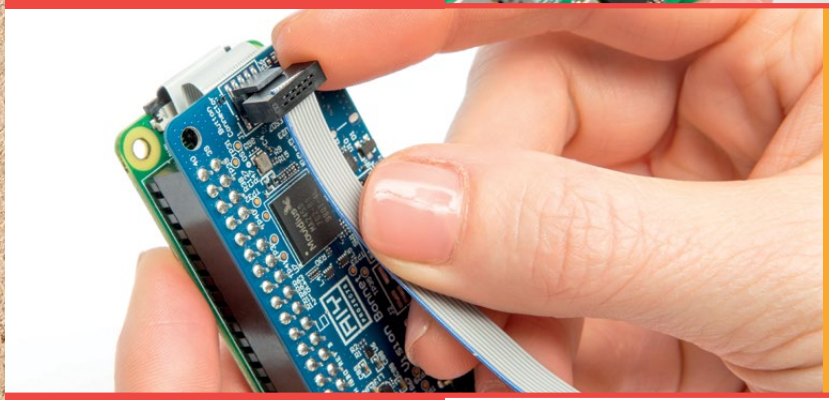
Here's how the various parts work to form the AIY Projects: Vision Kit. A complete step-by-step guide to the build is available at **magpi.cc/2AEwfgf**

>STEP-01

MIPI flex cable

The MIPI flex cable connects the VisionBonnet to the Pi Zero W board via the camera connector socket (the Camera Module is connected directly to the VisionBonnet later in the build). You gently pull back the black release lever on the VisionBonnet and slide in the MIPI cable, then secure the cable by pushing back the release lever. The process is then repeated on the Pi Zero W board.





>STEP-02

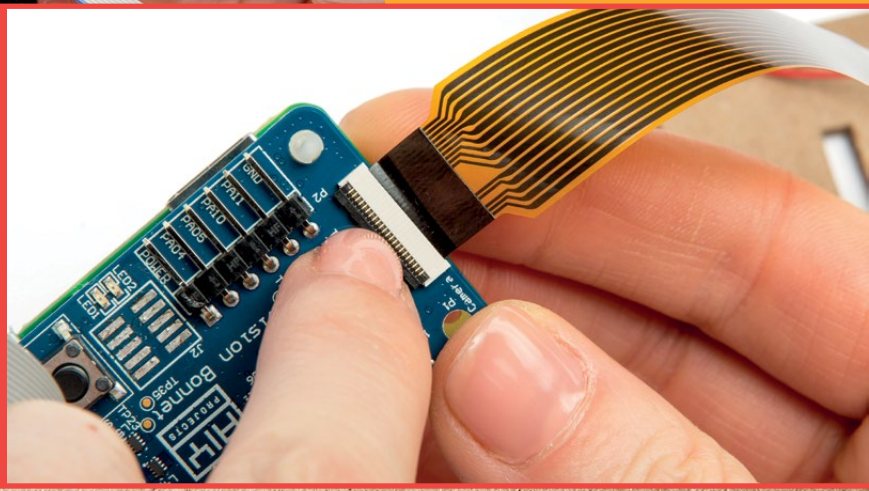
RGB LED button

The Vision Kit includes an RGB LED button (capable of providing visual feedback via different colours). The 50 mil ribbon cable is plugged it into the button connector on the VisionBonnet board. This is then used to connect the RGB LED Button to the VisionBonnet board.

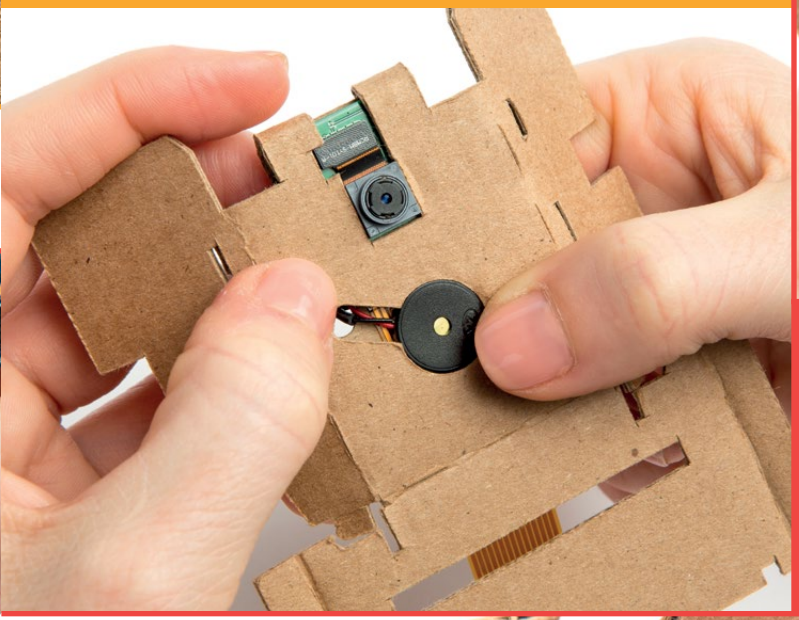
>STEP-3

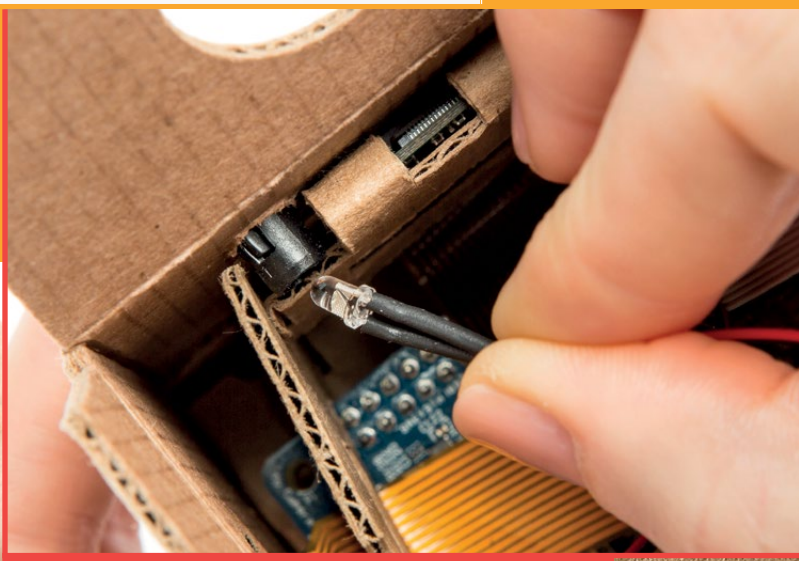
Camera

The Pi Camera Module is connected directly to the VisionBonnet (rather than to the Pi Zero W). The larger end of the Pi Zero camera flat flex cable connects to the Camera Module V2, and the smaller end of the Pi Zero camera flat flex cable is plugged into the VisionBonnet board connector.

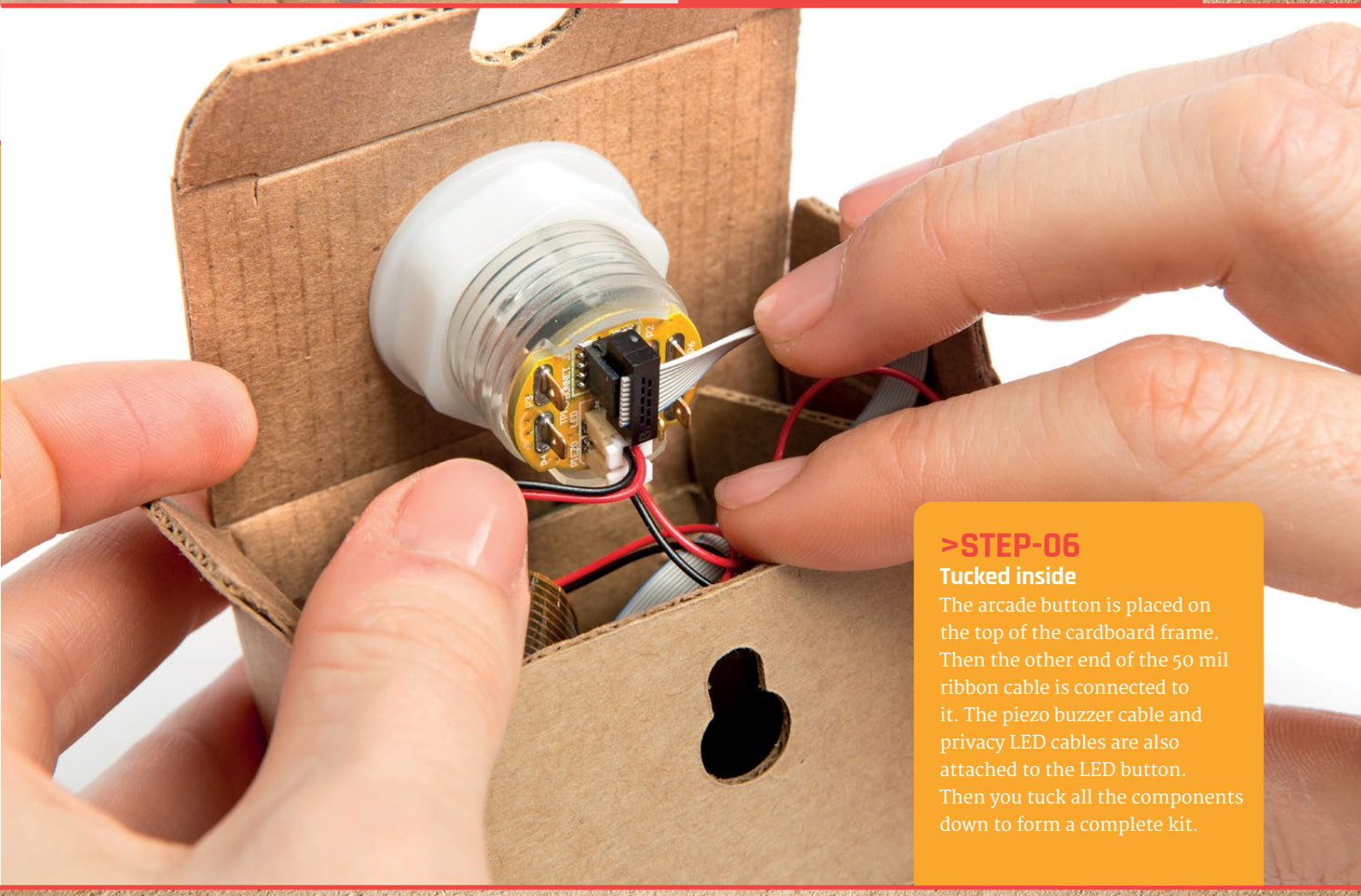


>STEP-04
Piezo buzzer
As you're assembling the cardboard frame, a piezo buzzer is inserted inside the frame. This provides simple audio, which, along with the multicoloured LED button, is used to provide basic feedback.





>STEP-05
Privacy LED
The privacy LED is inserted into the LED bezel and fitted to the front of the cardboard frame. This is used to provide a visual clue to users when the device is recording images. It's useful for feedback, and also good manners to let people know when they're being recorded.



>STEP-06
Tucked inside
The arcade button is placed on the top of the cardboard frame. Then the other end of the 50 mil ribbon cable is connected to it. The piezo buzzer cable and privacy LED cables are also attached to the LED button. Then you tuck all the components down to form a complete kit.

LEARN HOW IMAGE RECOGNITION WORKS

With your Vision Kit set up, you're ready to start exploring object detection with your Raspberry Pi

Attaching a VisionBonnet to your Pi Zero W enables it to perform machine vision tasks, where your projects can infer objects, detect faces, or even human emotions.

But what goes on under the hood? In this part of the feature, we're going to take a very high-level look at artificial intelligence and neural networks that are based on our understanding of the human brain.

In particular, we'll look at a special type of artificial neural network called a 'convolutional neural network'. This is the data structure that enables your Raspberry Pi to perform image detection.

This is a shallow introduction; dive a little deeper and you'll find a lot of mathematical structures, interesting algorithms, and lots and lots of connected data.

It's dizzying to behold, but fascinating and sits right at the cutting-edge of modern technological developments.

The good news is this: at the maker level, it is easy to add machine intelligence to your projects. Google is providing a detailed API and models which you can use to quickly add image recognition to your projects.

A bit of understanding goes a long way. So let's see what's going on inside the VisionBonnet.

Figure 1

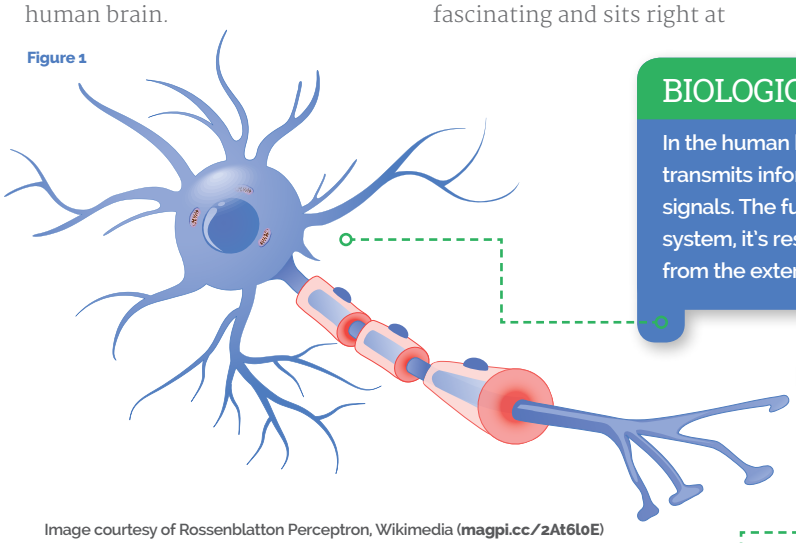


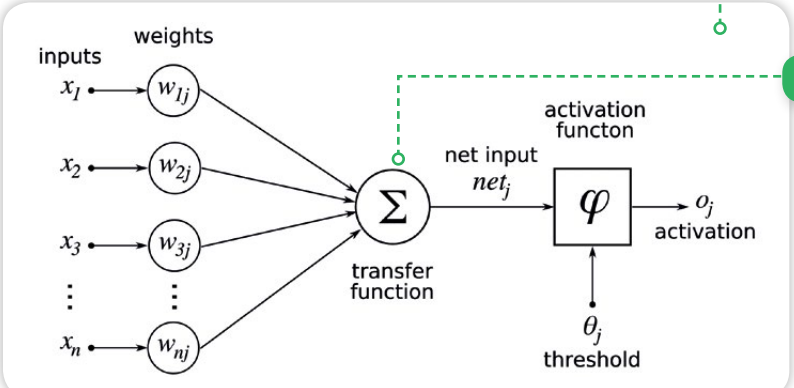
Image courtesy of Rossenblatton Perceptron, Wikimedia (**magpi.cc/2At6l0E**)

BIOLOGICAL NETWORK

In the human body, a neuron is an excitable cell which transmits information through electrical and chemical signals. The fundamental unit of the brain and nervous system, it's responsible for receiving sensory input from the external world.

ARTIFICIAL NEURON

Inspired by biological systems, neurons have been roughly modelled in software using algorithms.



TRANSFER FUNCTION

Neural networks are formed by connecting artificial neurons like this together in a computational graph. Pixels come in as input values, and they are multiplied by weights and a bias value is added. A computed value is then passed to the next neuron.

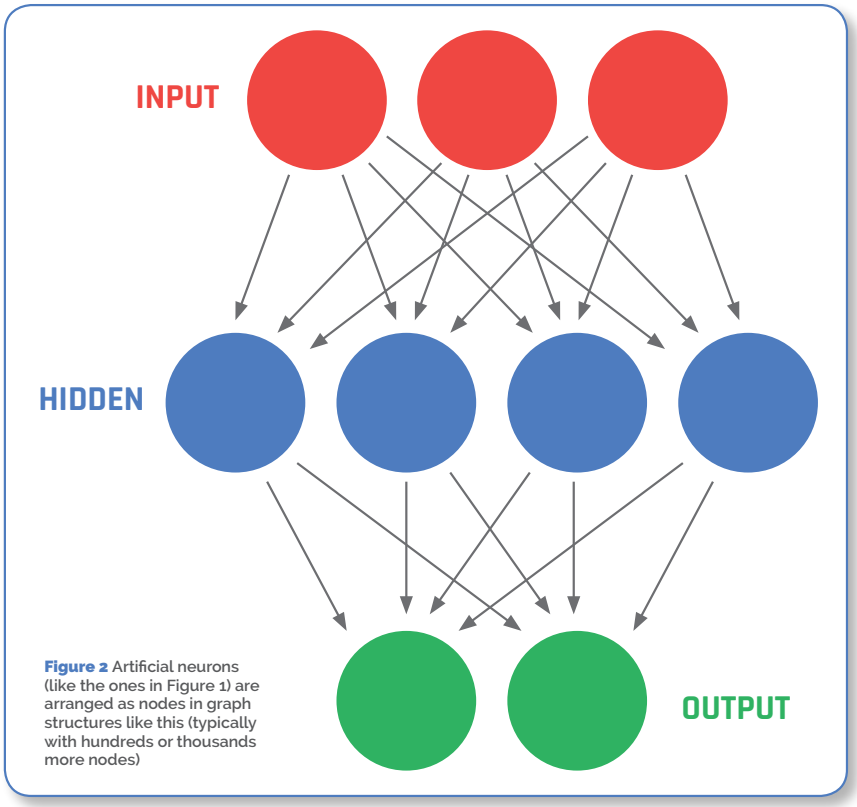


Figure 2 Artificial neurons (like the ones in Figure 1) are arranged as nodes in graph structures like this (typically with hundreds or thousands more nodes)

>STEP 01
Biological neuron

Take a look at the top half of our **Figure 1** on the left: biological and artificial neurons. This is of course an example of a biological neuron. Information arrives as a natural electrical signal via the dendrites, and if enough signal arrives in the neuron via dendrites, a signal is passed on to other neurons via the axon. Neurons are clustered together in the visual cortex to detect different shapes and other visual information. The patterns formed by clusters of 'firing' neurons enable us to make sense of what we see.

>STEP 02
Artificial neuron

Artificial intelligence, famously known as AI, attempts to mimic the behaviour of biological human neural networks using an artificial neuron, which is known as a 'perceptron'. This is shown in the lower half of **Figure 1** on the left. The perceptron also has inputs and outputs. Here, the inputs are typically a value from each pixel in an image.

>STEP 03
Weights and biases

So how does a perceptron know when to activate? Information comes into the artificial neuron as floating-point numbers. It's then multiplied by a weight (which is calculated and changes as the neuron is 'trained'). A bias number is added and another mathematical function is used as an activation layer – it's this number that is passed on to the next perceptron.

>STEP-04
Neural networks

There are approximately 100 billion neurons in the human brain, so we need plenty to make our machine vision work. The artificial neurons are connected together to form a 'Neural Network' (**Figure 2**). The input layers at the top represent the data you start with (such as the pixels in an image) and the output layer is an estimate of the output (such as a matching label, like 'dog' or 'smile'). In between are hidden layers, which don't see the whole network, just the previous and next layers.

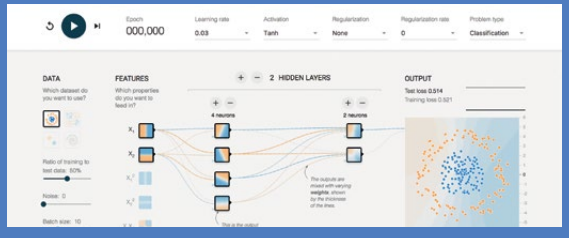
object_detection.py

```
import argparse
from PIL import Image
from PIL import ImageDraw

from aiy.vision.inference import ImageInference
from aiy.vision.models import object_detection


def _crop_center(image):
  width, height = image.size
  size = min(width, height)
  x, y = (width - size) / 2, (height - size) / 2
  return image.crop((x, y, x + size, y + size)), (x, y)


def main():
  parser = argparse.ArgumentParser()
  parser.add_argument('--input', '-i', dest='input',
required=True)
  parser.add_argument('--output', '-o',
dest='output')
  args = parser.parse_args()

  with ImageInference(object_detection.model()) as
inference:
    image = Image.open(args.input)
    image_center, offset = _crop_center(image)
    draw = ImageDraw.Draw(image)
    result = inference.run(image_center)
    for i, obj in enumerate(object_detection.get_
objects(result, 0.3, offset)):
      print('Object #%d: %s' % (i, str(obj)))
      x, y, width, height = obj.bounding_box
      draw.rectangle((x, y, x + width, y + height),
outline='red')
    if args.output:
      image.save(args.output)

if __name__ == '__main__':
  main()
```

TENSORFLOW PLAYGROUND

A great way to get a visual understanding of neural networks is to use the TensorFlow Playground. This interactive website enables you to test out different combinations of neural network elements against datasets (blue and orange dots arranged in different patterns). You can see how adding features and hidden layers can make the neural network better at pattern recognition.

playground.tensorflow.org



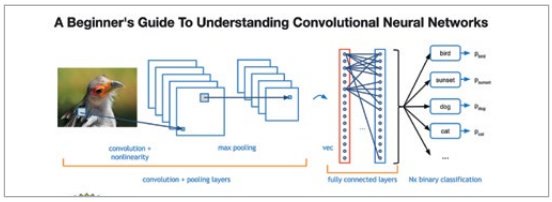
LEARN MORE ABOUT NEURAL NETWORKS

Here are some resources for learning more about artificial neurons, neural networks, and convolutional neural networks.

Cats & dogs & convolutional neural networks

A great coding example for building a cat and dog detector with TensorFlow.

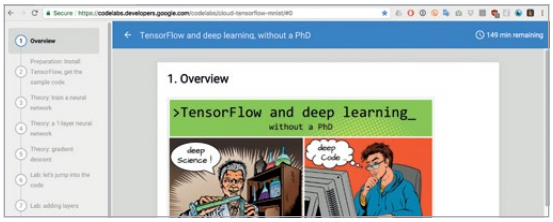
magpi.cc/2jl2qcU



A Beginner's Guide To Understanding Convolutional Neural Networks

A thorough explanation of how neural networks work. This page outlines how they break down images into shapes to accurately detect different objects.

magpi.cc/2jlUUhX



Tensorflow and Deep Learning without a PhD

A free resource from Google that takes you through the process of creating a neural network that can recognise handwritten digits.

magpi.cc/2jlDdzk

Complete Guide to TensorFlow for Deep Learning with Python

If you're serious about learning more about how TensorFlow works and the creation of artificial neural networks, then this is the course to sign up for. It costs £20, but is often on sale, and can be picked up for as little as £10 if you're patient.

magpi.cc/2jnE7LM

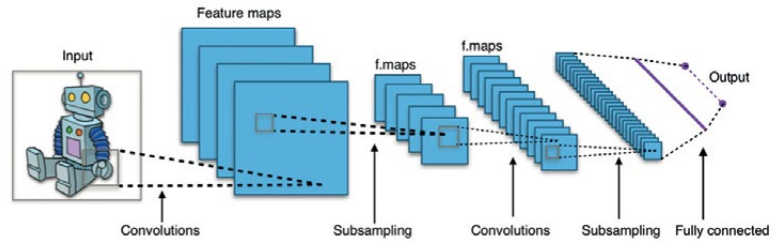


Figure 3 There are many different types of neural networks, specialised for different use cases. For computer vision and natural language processing, the most common type is the convolutional neural network (CNN). It breaks up images into small squares to identify common shapes and features (such as arcs, circles, dots, and lines). It's based on our understanding of the biological cortex. Image credit: Wikimedia

>STEP-05

Deep neural networks

More layers give greater accuracy and also enable the artificial neural network to handle far more complex tasks.

So in our artificial vision model, some layers could detect the edges of images; some could note things like eyes, or eyebrows, or lines of the face, or the curve of a smile.

But there's a performance trade-off. So designing a good neural network is a balancing act.

If you have three or more layers, you get a deep neural network, which is where you get the term 'deep learning' from.

>STEP-06

Biological neural network

Getting back to the biological vision for a bit. Back in 1981, two professors named Hubel and Wiesel won the Nobel prize for studying the visual cortex in mammals. What they discovered was that neurons in the visual cortex have a small receptive field. They only look at small parts of what you see. They overlap to view the larger image. Different clusters of neurons are activated when they identify certain shapes: circles, horizontal lines, vertical lines, arcs, and so on.

>STEP-07

The convolutional neural network

This brings us to the big discovery: the convolutional neural network. This was first outlined in 1998, in a paper called *Gradient-Based Learning Applied to Document Recognition*, by Yann LeCun and others (**magpi.cc/2BHJ48A**). The convolutional neural network mimics the biological neural network discovered by Hubel and Wiesel.

>STEP-08

Breaking it down

Convolutional neural networks are designed specifically for image recognition. The CNN breaks down an image into increasingly small squares, called 'convolutions' or 'filters', in a process known as 'subsampling'. See **Figure 3**, above.

TENSORFLOW PROCESSING UNIT

TensorFlow is a Google-sponsored software library used to develop neural network architectures, such as the convolutional neural network we've outlined here.

Large sets of labelled data are used to train the network into a model for a purpose.

Google researchers have developed high-performance neural networks for image recognition, working best with specialised hardware. This hardware revolves around a tensor processing unit (TPU), an integrated circuit developed by Google specifically for machine learning. The chip on the VisionBonnet is acting as a TPU.

Each artificial neuron (perceptron) is connected to a small number of nearby neurons. These are grouped into small neighbourhoods that (like our biological neurons) detect shapes inside images: horizontal lines, arcs, circular dots, and so on.

>STEP-09
Training stage

So now we have our convolutional neural network, how do we get it to detect cats from dogs, or know when a human is smiling or frowning? The network is trained using thousands of training images against known labels (such as 'dogs' or 'cats') to create a model. This model is then tested against images it's never seen before to see how accurate it is. If the model is any good, you can use it in your projects.

>STEP-10
Loading models

For the most part, we expect folks to start by uploading models made by Google. Later you'll use models built by the community. Want a sheep-detector for your petting zoo? Need to keep an eye on a tool on a production line and know when it's about to fail? Just ask other members of the AIY Projects community to help.

Google has already created three models that you can load onto your Vision Kit: a cat, dog, or human face detector; a human face and sentiment detector; and a model that identifies 1001 different commonplace objects.

>STEP-11
Follow the test code

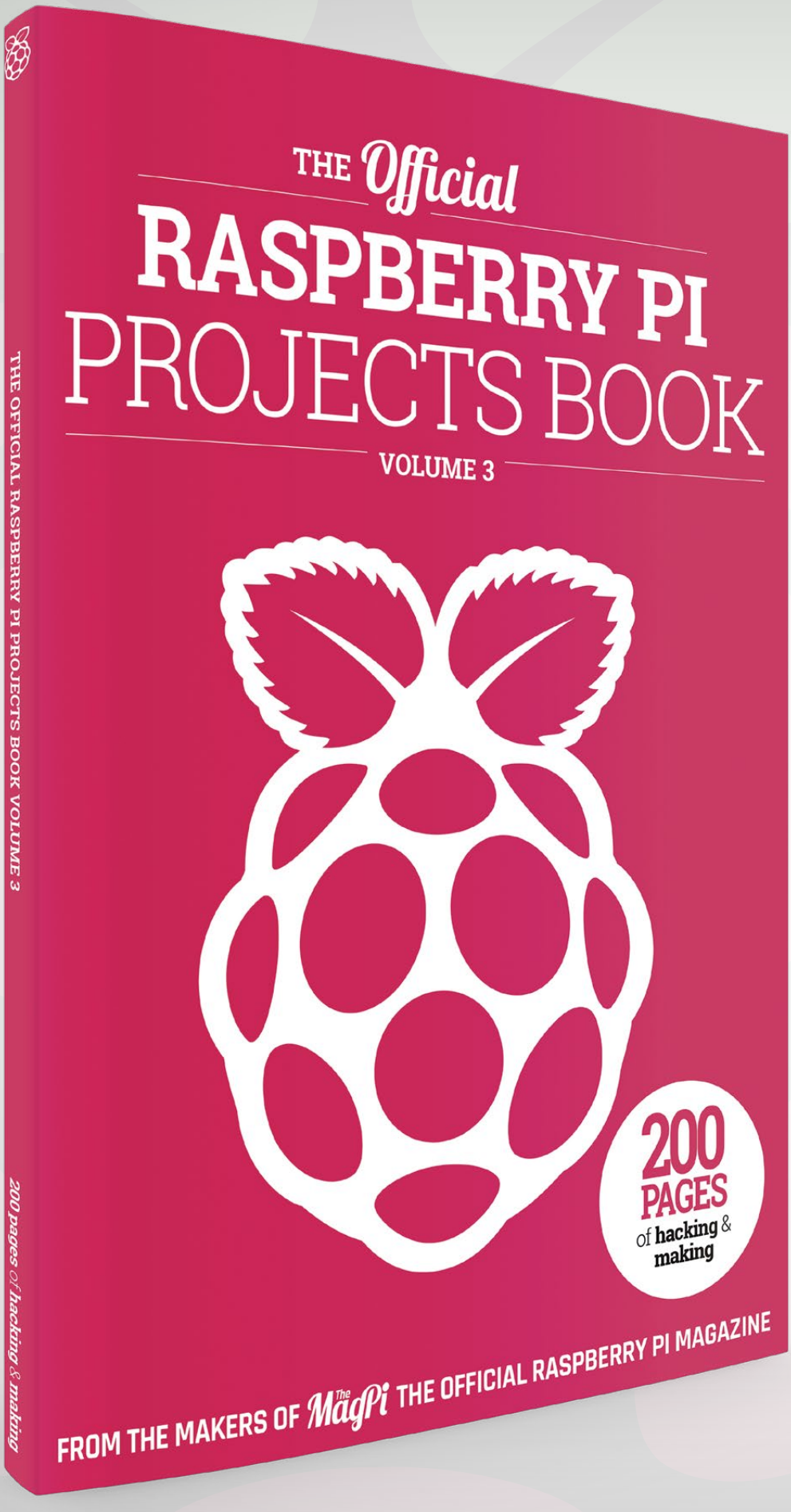
There are three pieces of example code in this feature related to AIY Vision Kit and your projects. The first two, **object_detection.py** and **image_classification.py**, accept an image file and infer objects or classify images. The third uses the Pi Camera and snaps a photo if it detects faces. Take a look to see what's possible.

image_classification.py

```
import argparse
from PIL import Image

from aiy.vision.inference import ImageInference
from aiy.vision.models import image_classification


def main():
  parser = argparse.ArgumentParser()
  parser.add_argument('--input', '-i', dest='input', required=True)
  args = parser.parse_args()

  with ImageInference(image_classification.model()) as inference:
    image = Image.open(args.input)
    classes = image_classification.get_classes(inference.run(image))
    for i, (label, score) in enumerate(classes):
      print('Result %d: %s (prob=%f)' % (i, label, score))

if __name__ == '__main__':
  main()
```

face_detection.py

```
from aiy.vision.inference import CameraInference
from aiy.vision.models import face_detection
from picamera import PiCamera


def main():
  with PiCamera() as camera:
    camera.resolution = (1640, 922)
    camera.start_preview()

    with CameraInference(face_detection.model()) as inference:
      for result in inference.run():
        if len(face_detection.get_faces(result)) >= 1:
          camera.capture('faces.jpg')
          break

    camera.stop_preview()


if __name__ == '__main__':
  main()
```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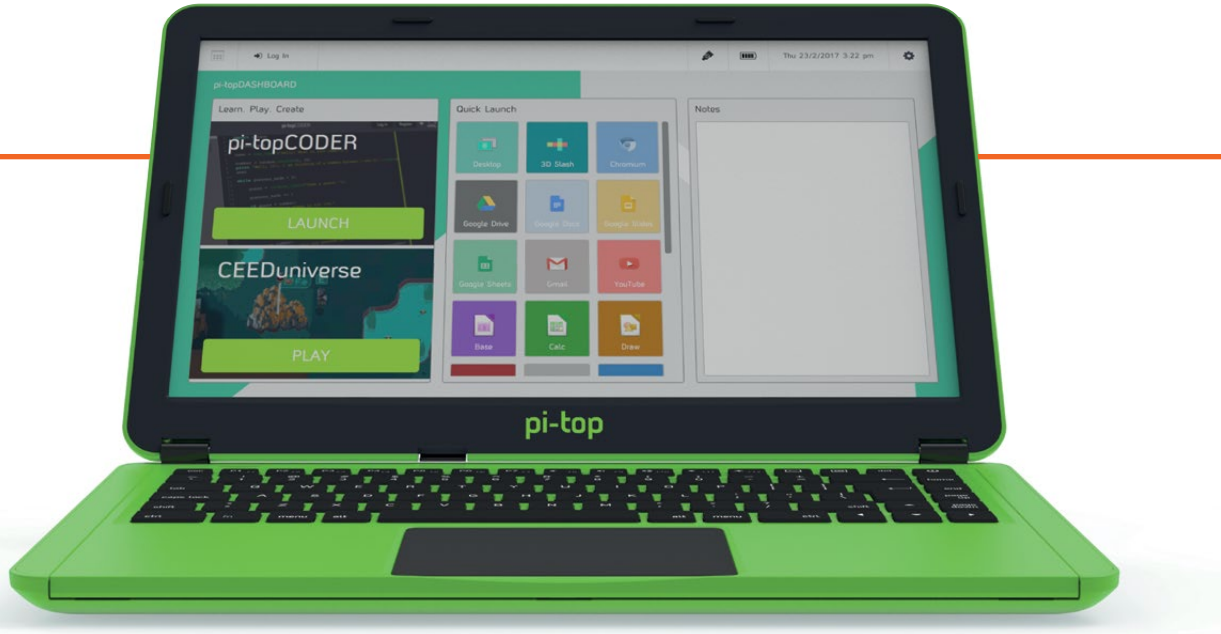


Maker Says

"A modular laptop that gives you the tools to complete amazing DIY projects"

pi-top

PI-TOP

Vastly improved build quality and fantastic starter projects.
By **Lucy Hattersley**

The second-generation pi-top laptop is a device that has been long awaited by the Raspberry Pi team. While the first attempt was an interesting home-brew attempt to 3D-print a laptop, this is the point where it goes professional.

Inside the box you get a pi-top housing, Inventor's Kit, power supply and, of course, a Raspberry Pi 3 computer.

The pi-top kit does require some assembly. The Raspberry Pi is screwed into place behind the keyboard. It takes up two USB ports, leaving two free and accessible from behind the laptop case. A Hub PCB slides to the right of the Raspberry Pi and hooks into the 3.5mm jack and HDMI socket.

A metal Cooling Bridge bridges the gap between the Hub PCB and GPIO pins on the Raspberry Pi. It's required to power the Raspberry Pi, however, and you can't remove it and access the GPIO pins on your Raspberry Pi directly.

The Cooling Bridge blocks off access to the GPIO pins, and prototyping takes place on the separate pi-topPROTO+ board (which has a pin breakout along with analogue pins).

Setup is easy. Really easy. It literally takes five minutes. Obviously this is good in one respect, because it reduces the potential for problems.

We can't help wishing the build had slightly more to it. The keyboard, screen, trackpad, and battery all come in the pre-assembled kit and the assembly process felt vaguely superficial.

Design notes

There are some truly great touches to the design. Let's start with its marquee feature, a sliding keyboard that moves down to reveal the inner components. It slides smoothly and clicks into either position.

The chiclet-style keyboard is a joy to type on, with the same level of quality you'd find on an Intel-based laptop.

You can keep typing with the keyboard down thanks to a clever sliding cable system. And behind the keys lie two magnetic strips. Parts such as the PROTO+ and separate pi-topPULSE accessory clamp onto the rails.

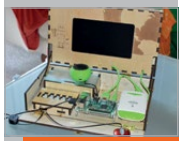
There's even a neat multi-tool accessory. One end is used as a screwdriver for the Raspberry Pi and Cooling Bridge. The other is a neat clamp that holds a microSD card so you can slide it in and out of the Raspberry Pi without having to remove the board. Clever stuff! We hope whoever designed the multi-tool got a pay rise. It also clamps on to the magnetic rail so you can take it with you.

Above the keyboard sits a glorious 1920×1080 display. It's a vast improvement on the previous model, and is surrounded by a nice bezel with rubber feet to hold it neatly against the keyboard when closed.

Related

PIPER COMPUTER KIT

A wooden computer and electronics kit with a built-in screen. Not a complete laptop, but a similar solution for teaching kids to code and use electronics.



£299 / $299

buildpiper.com

pi-top.com

£260 / $319

All of which is powered by a battery providing six to eight hours of life. We easily got a full day out of it, and it held charge for a week without losing all its power.

Beneath the keyboard is a larger trackpad which – and it pains us to say this – sucks. It is sensitive to taps and brushes that frequently move the cursor unintentionally. We ended up connecting a mouse instead of using the trackpad.

> "The same level of quality you'd find on an Intel-based laptop"

PolarisOS

Once everything is set up, you can start using the pi-top with the custom PolarisOS software. This is a custom build of Raspbian Jessie with extra software such as Google Drive and Google Docs. You also get neat extras such as Turtle ART and 3D Slash.

Alongside Minecraft Pi and Python games is an extra offering called pi-topCEED Universe. This is a neat top-down adventure game where you have to use code to solve challenges.

And there's a built-in app called pi-topCODER. This contains worksheets for everything from getting started to building electronics projects. Set up an account with pi-top and you get tracking stats for the number of lines of code you've created, and the worksheets you've completed.

And you can always run Raspbian Stretch, which was recently updated with pi-top extras such as a battery gauge.

Is the price right?

At £259 the pi-top is by no means extravagant in the laptop world. But it's a far cry from the $35 computer that the Raspberry Pi itself represents. Even at £259 you don't get everything on offer. Accessories like the pi-topPULSE ($49.99) with an RGB matrix cost extra. You can even spend an extra $19.99 for a speaker, which isn't included in the base package (although you can listen to sound using the headphone socket).

Of course, buying a Linux laptop for the same price misses the point. Along with the pi-top you get a fantastic Inventor's Kit containing LEDs, buttons, SH-SR04 echolocation sensor, and a potentiometer. And you can prototype on a Raspberry Pi using the GPIO breakout pins on the pi-topPROTO+).

And let's not forget it includes Mathematica. For some people, this alone could be worth the price of admission. Mathematica costs £210 for a Home & Hobby licence. It's free with Raspbian.

The pi-top also contains three high-quality cardboard cut-out kits and a raft of software and workshops for kids. This enables kids to build a cardboard robot, spaceship, and music maker alongside learning basic coding and electronics skills. We think these are great projects that perfectly blend physical construction activity with coding. Well done!

Last word

An amazing environment for kids to learn computing and digital making. And it's pretty good for adults who want to prototype Raspberry Pi projects on the move. Vastly improved upon the original pi-top, but still with quirks. We're taking off a star for the trackpad, but connect a mouse and this is the perfect laptop.

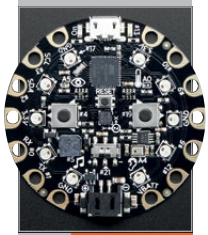
BEARABLES BADGE KIT

This light-up LED badge can be sewn onto clothes and triggered by a sensor

Related

CIRCUIT PLAYGROUND

This ring of NeoPixels has four built-in sensors, plus pads around the outside to connect others using crocodile clips. It's programmable on any computer (including the Pi) using the Arduino IDE.



£23 / $20

magpi.cc/2jnRyu0

Pimoroni's Bearables collection offers a choice of two cute animal LED badges – bear and fox – along with a couple of sensors that can be attached to them using conductive thread. While the badges and sensors are available separately, the complete kit includes either a bear badge with motion sensor, or a fox badge with light sensor. Both versions include a generous 3 metres of conductive thread, along with a CR2032 coin cell that provides 3–4 days of active use (i.e. when the badge is not in sleep mode).

On its own, the badge can be operated manually by repeatedly pressing the tiny button on the side to switch between 12 different

BEARABLES BADGE KIT

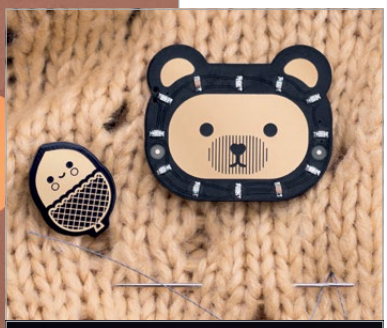
magpi.cc/2jnkZMW

£13 / $17

Maker Says

"A range of woodland-themed wearable LED badges and sensors"

Pimoroni



Above The neatly packaged kit includes everything you need

Right Available in fox and bear styles, the badges feature 12 coloured LEDs

LED patterns: a good selection, including chase lights and fades. The LEDs are single colour, but come in six shades: blue, green, yellow, orange, red, and pink. There's also the possibility of creating your own custom patterns using a Raspberry Pi.

sensor will then trigger the LEDs through motion or lack of light, depending on its type.

The badge can be hooked up to a Raspberry Pi via I²C. This involves soldering wires (or a header) to metal pads on the rear of the badge and connecting them to

> "The kit includes either a bear badge with motion sensor, or a fox badge with light sensor"

When sewing the badge to a garment or bag, you need to connect each of its two metal hooks to one of those on the sensor. Polarity doesn't matter, but you need to avoid the two lengths of conductive thread touching. Getting a good enough connection also requires winding the thread four or five times around each hook – it's best to secure it with a blob of clear nail varnish, too. Upon holding the badge button down, the attached

the relevant GPIO pins. Helpfully, Pimoroni has created a Bearables Python library (**magpi.cc/2AcQ3H6**) enabling you to control individual LEDs and respond to button presses. Since the badge hooks can read raw ADC values (0–255), they should be usable with pretty much any analogue sensor. Not only that, but they can read GPIO pins pulled high or low, opening up all sorts of possibilities for triggering LED patterns from the Pi.

Last word

Excellent value for money, the badge kit has everything you need to sew your interactive badge and sensor to clothes – although it should be noted that they don't like water, so don't put them in the wash! Best of all, you can link the badge up to a Pi to create custom light patterns and a whole lot more.

★★★★★

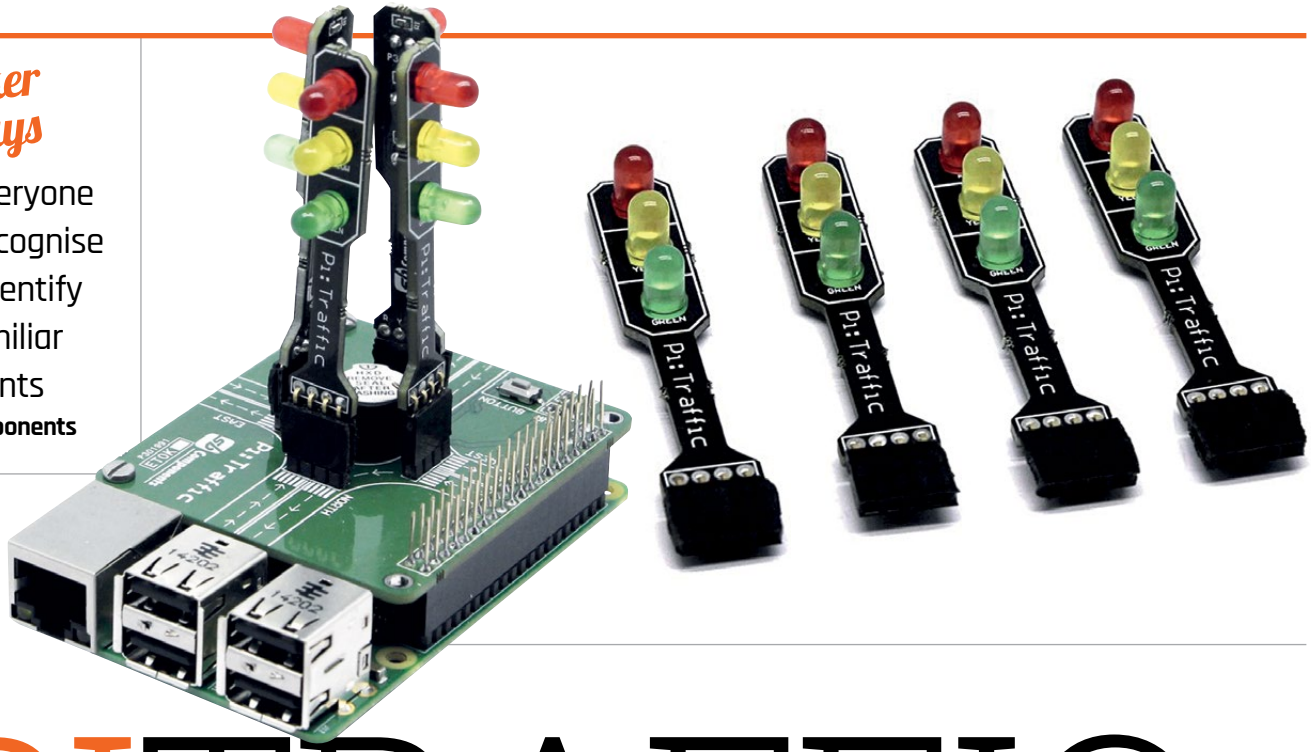
magpi.cc/2ANbVcw

£12 / $16

Maker Says

"Everyone will recognise and identify its familiar elements"

SB Components



PITRAFFIC

Build a working set of traffic lights and control them with code. By **Lucy Hattersley**

Related

CAMJAM EDUKIT 1

It might only have three LEDs, but you build a traffic light yourself with jumper wires and resistors. Comes with a set of printable worksheets.

£5 / $6

magpi.cc/2ANOBwZ

Setting up LED lights is a common starter project, so much so that we frequently feature it in our beginner's guides. Just set up an LED and use a bit of code to turn a light on and off.

It's common for educators to turn to traffic lights as inspiration for a quick follow-on project: LEDs are readily available in red, yellow (amber) and green. Students can see the relationship between the code they create and physical objects being controlled in the real world.

Setting up traffic lights is a hassle, though. You need at least three LEDs for each light, plus a button if you're creating a pelican crossing. Setting up more than one set of lights quickly becomes a tangled bird's nest of wires, resistors, buttons, and LEDs.

The PiTraffic HAT solves this by placing four traffic light sticks on top of the board. It also features a button to one side, and a piezo buzzer in the middle of the traffic lights (so your pelican crossing can beep, just like in the real world).

Setup is simple. Just plug the four traffic light sticks into the four sets of pins on top, and connect the PiTraffic HAT to the GPIO pins on any Raspberry Pi that has a 40-pin header.

Then you should download test code from GitHub (`git clone magpi.cc/2ymyx0E`).

After importing the PiTraffic code, you create instances of `Traffic` objects for each light, such as `SouthRed = Traffic("SOUTH", "RED")`. Once created, these are controlled using `on()` and `off()` methods, such as `SouthRed.on()` and `SouthRed.off()`.

The only thing missing for us was Scratch support, which SB Components inform us is coming soon. The inclusion of Scratch will make this a compelling starter project for students. In the meantime we enjoyed using the Python API to code our lights.

Last word

A great starter HAT that takes much of the tangle out of a classic project. Students can test out traffic light code and see their results running in a miniature recreation.

★★★★☆

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Maker Says

"This neat little board adds a programmable power switch to your Raspberry Pi"

Nanomesher

RASPBERRY PI POWER SWITCH

Rob Zwetsloot looks at a simple, functional addition to the Raspberry Pi that goes the extra mile

One of the things we always hear about concerning the Raspberry Pi is that a lot of people would like it to have a power switch of some kind. There are a few solutions for this you can try, ranging from a simple USB switch to custom, soldered-on buttons. This Raspberry Pi Power Switch is a little different, though.

At least it *can* be different – out of the box you get a little circuit board that connects to the Raspberry Pi GPIO, and also acts as a bridge to the USB power. You can then use it with the remote it comes with, along with some extra code you need to install yourself, to remotely power your Pi on and off with a press of a button. Nice and simple, and exactly what most people want. It's small as well, so should slip into most projects.

The real magic of the board comes from the programmable ATtiny MCU controller. It's a completely hackable chip that sits on the Power Switch board but can be removed and reprogrammed to provide other functionality with the remote.

The catch is that you need to reprogram it via an Arduino-compatible platform like an Uno. If you pay a bit more, you can get these Arduino devices with the switch if you don't already own one, but you'll need to wire it up yourself to the Arduino with a breadboard.

You can hack it to recognise more signals from the included remote (or indeed any compatible remote), and even change the timings and function of the shutdown. Want a button in case you need to do a hard reset? You can add that by hacking the chip and then replacing it on the board. Very simple.

We like the design of the board, but we feel it would function better as some form of HAT, even if just as an optional way to attach it to the Raspberry Pi. Otherwise, the Power Switch works well enough and does the job of being able to turn the Pi on or off safely.

Last word

Going beyond what you'd expect of a typical on/off switch by making it hackable is a very novel idea. However, we feel like there could be some minor improvements to its connectivity.

★★★★☆

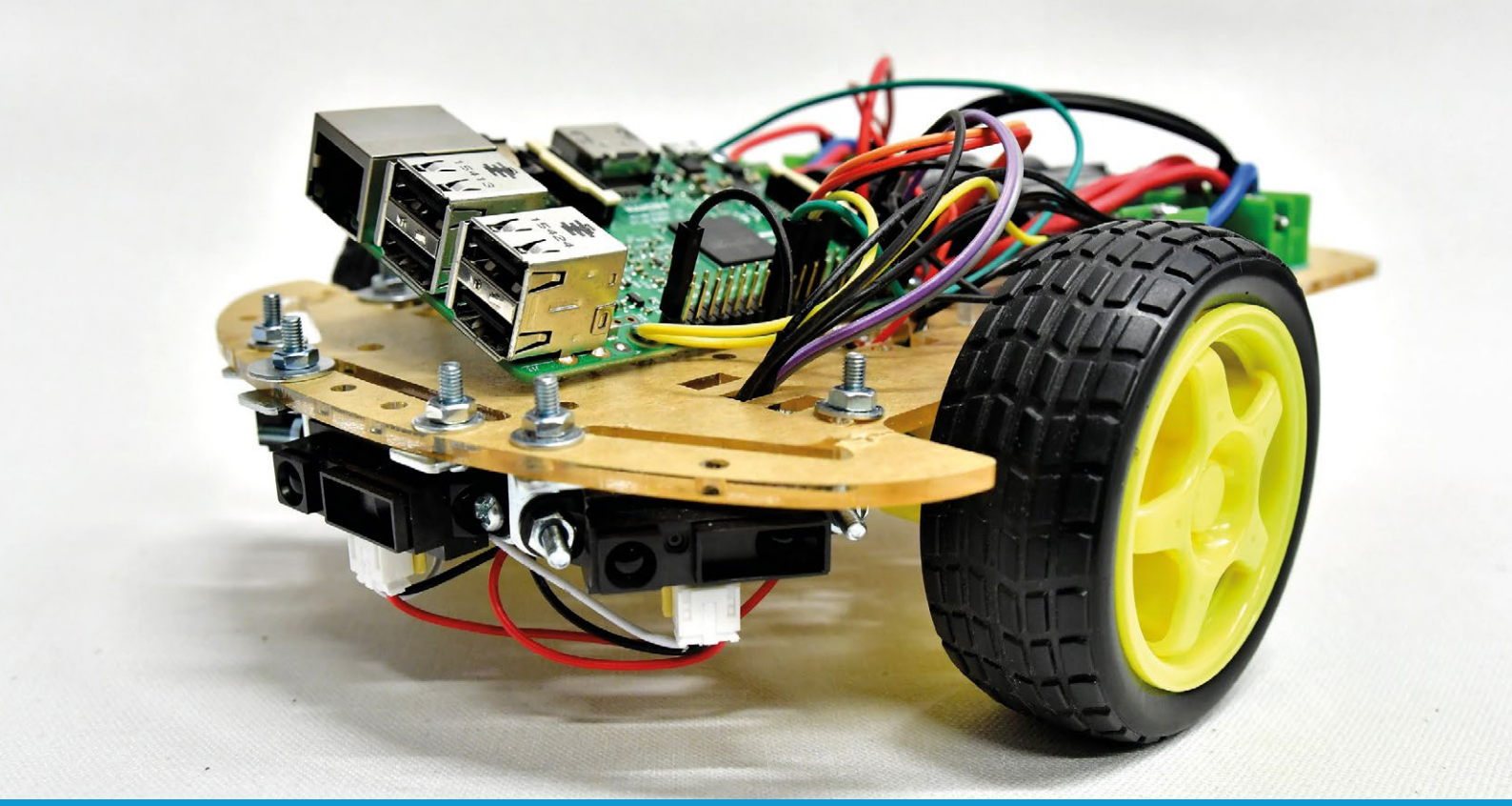
Related

PI SUPPLY SWITCH

A similar bit of tech allows you to smartly turn on and off a Pi without it just being a hard power cut, although this one lacks a remote.

£15 / $20

magpi.cc/2Begq2Z



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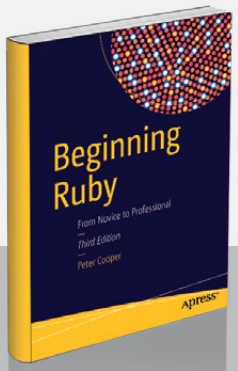
RASPBERRY PI BESTSELLERS RUBY

While Rails is less trendy, Ruby remains the cornerstone of much DevOps software.

BEGINNING RUBY 3RD EDITION



Author: Peter Cooper
Publisher: Apress
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magpi.cc/2knB8pl

Ruby, OOP, and good programming practice combined in a volume that touches on all the essentials from file handling through to documenting your code. A great intro for all, including coding beginners.

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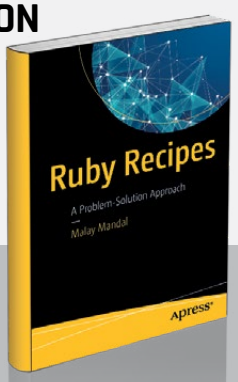

Author: Malay Mandal
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Cookbook-style collection of code snippets and short how-tos covering common scripting uses and teaching a fair bit of Ruby along the way in object-oriented and even functional programming style.

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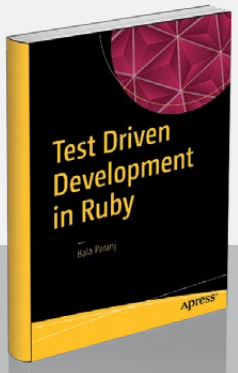
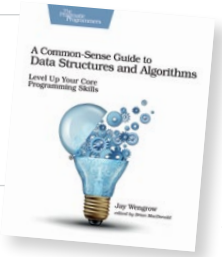


Author: Bala Paranj
Publisher: Apress
Price: £31.99
ISBN: 978-1484226377
magpi.cc/2kqCK2c

A clear-sighted look at incorporating TDD into your coding workflow, based in Ruby, but strong on general principles that you'll be able to take away to Python and other languages.

A COMMON-SENSE GUIDE TO DATA STRUCTURES & ALGORITHMS



Author: Jay Wengrow
Publisher: Pragmatic Bookshelf
Price: £36.99
ISBN: 978-1680502442
magpi.cc/2krltWm

Data structures and algorithms are what programming, essentially, is all about. While it's easy to get started in coding, if you've not had a formal computer science education, or if time and other activities have dimmed the memories, Wengrow's carefully structured guide aims to fill in the gap.

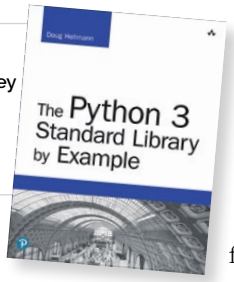
It's also an essential subject if you've turned self-taught coding into a career, and have been flummoxed in a job interview when the questions turned to, say, Big O notation. We've reviewed a few algorithm books at either end of the technical spectrum, but this one is squarely in the middle, aimed at coders, but those lacking in the rigorous mathematical education.

And the explanation of Big O, and many other topics, should be graspable by any who have struggled with denser books.

Most importantly, this is a book with a practical purpose for programmers – speeding up your code. Having shown you how to understand and to measure the efficiency of your code, you'll see how the right algorithm and data structure for your project can make orders of magnitude of difference in the speed and scalability of a program. Clear explanations, essential theory, practical outcome – a great combination.

Score ★★★★☆

THE PYTHON 3 STANDARD LIBRARY BY EXAMPLE



Author: Doug Hellmann
Publisher: Addison Wesley
Price: £47.99
ISBN: 978-0134291055
magpi.cc/2BNzRwq

The Python Standard Library is the 'batteries included' part of the language, giving the programmer a huge boost by providing them, inter alia, with modules for database connection, GUIs, networking, regular expressions, and unit tests. Doug Hellmann has long documented interesting and useful modules from the library in his popular Python Module of the Week (PyMOTW) blog, which led to the previous edition of this book. Blog and book are now both updated for Python 3.

Modules get illustrated with code and discussion, aimed at intermediate-level developers who already have enough understanding of the language and its ways to follow along. The examples manage, through more than 1300 pages, to always hit the mark. Between Hellmann's clarity of thought and Python code's general readability, this is a great learning resource.

Note, there have been complaints about the code formatting of the e-book version, but the printed version (reviewed here) is correctly formatted. And this is a book that every Python programmer should have on their bookshelf, not just for reference, but to regularly take down and work through a Python module or three. Advanced abilities in Python consist largely of knowing what is available, and not wasting time reinventing work already done. An essential purchase.

Score ★★★★★

ACCESSIBILITY FOR EVERYONE

Author: Laura Kalbag
Publisher: A Book Apart
Price: $37.50
ISBN: 978-1937557614
magpi.cc/2ksBlb9

"Design decisions made in the name of accessibility generally benefit everyone, because all technology is assistive," says Kalbag, midway through this excellent look at the why and how of accessibility – a topic that seems to vex some projects and websites so much that they ignore it entirely! Those who don't access the world via screen, mouse, and keyboard in exactly the same fashion are often inadvertently sidelined.

Fortunately, there are some relatively easy ideas to incorporate accessibility into your workflow: universal design makes a site easy to read and understand for everyone. We all, at different stages in our lives, "traffic between times of relative independence and dependence," needing more or less assistance to see, hear, interact with, or understand a website or app.

Foremost, setting up an accessibility policy – based on "extensive research into the needs of your target audience" – means that you have an agreed basis in the project for putting everyone's needs into each stage of the design. The practical and straightforward steps you can take – from content and design, through legal considerations, to testing – are outlined systematically by Kalbag, and always combined with a good dose of common sense. A timely look at an essential topic.

Score ★★★★☆

R FOR EVERYONE 2ND EDITION

Author: Jared P Lander
Publisher: Addison Wesley
Price: £24.99
ISBN: 978-0134546926
magpi.cc/2krzIKV

While tremendously popular, in no small part thanks to the rapid growth in data science, R is not as easy to get started with as some languages – such as Python – thanks to its complexity. This is a language that can do much with statistics, algebra, and machine learning – but steering a path through to data science mastery in R, unless you have a lot of time on your hands, means knowing which bits to ignore.

Basic mathematical use, data structures, and graphing tools precede programming basics like control flow, showing R's strengths and main use cases. Following these come several chapters of practical data-led tutorials highlighting essential R packages, like dplyr and purrr, statistical and linear models, and techniques from data reshaping to K-means clustering.

In *R for Everyone*, Lander takes you on a structured path through the 20% or so of key R functionality which will enable you to manipulate and visualise data, and you won't feel short-changed by the time you reach the end. Lander combines the deep knowledge of a professional data scientist with the clear thinking of an experienced instructor. Nothing is oversimplified, but the confident beginner will be well rewarded.

Score ★★★★☆

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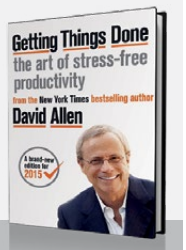

Author: David Allen
Publisher: Piatkus
Price: £13.99
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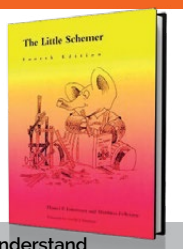

Authors: Daniel P Friedman & Matthias Felleisen
Publisher: MIT Press
Price: £32.95
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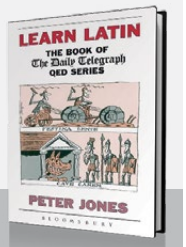
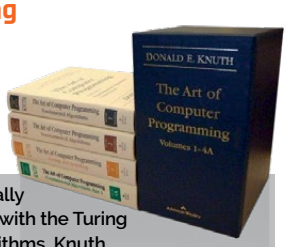


Author: Peter Jones
Publisher: Gerald Duckworth
Price: $14.99
ISBN: 978-0715627570
magpi.cc/2kpomad

Latin gives us many scientific root words, has a lovely logical structure, and learning it will stimulate your brain.

Resolution: Become an algorithm adept!

The Art of Computer Programming

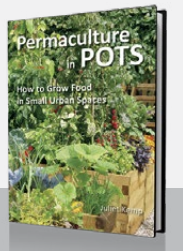


Author: Donald Knuth
Publisher: Addison Wesley
Price: £150
ISBN: 978-0321751041
magpi.cc/2krFKv4

Start your heroic struggle to really understand computer science, with the Turing Award-winning master of algorithms, Knuth.

Resolution: Get outside everyday

Permaculture in Pots

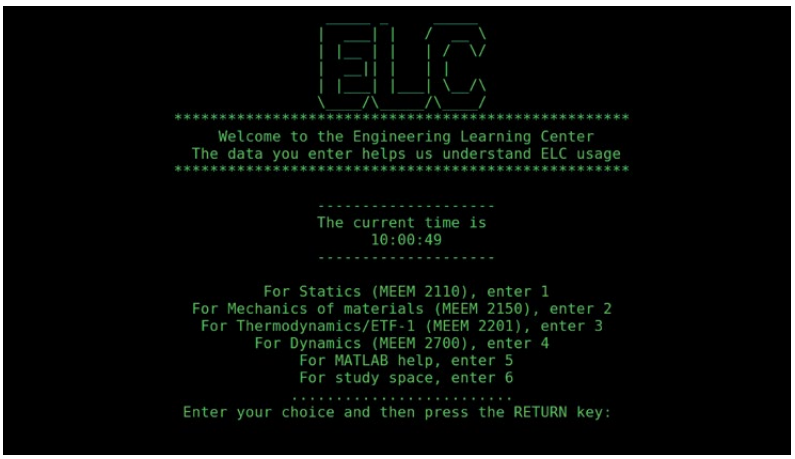


Author: Juliet Kemp
Publisher: Permanent Publications
Price: £12.95
ISBN: 978-1856230971
magpi.cc/2kpoXZv

Take a screen break; connect with the soil and elements for a few minutes, and grow some tasty food.

Aneet Narendranath

Occupation: University lecturer

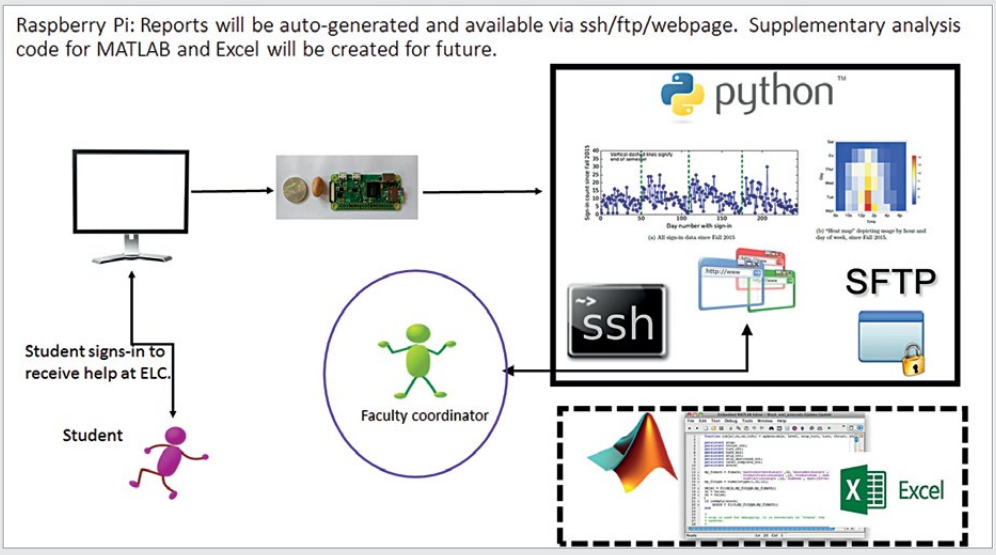

ELC
****
Welcome to the Engineering Learning Center
The data you enter helps us understand ELC usage
****
The current time is
10:00:49
For Statics (MEEM 2110), enter 1
For Mechanics of materials (MEEM 2150), enter 2
For Thermodynamics/ETF-1 (MEEM 2201), enter 3
For Dynamics (MEEM 2700), enter 4
For MATLAB help, enter 5
For study space, enter 6
Enter your choice and then press the RETURN key:

UNIVERSITY STUDENT DATA COLLECTION POWERED BY PI

Lowering the costs of a university's student service was only one of the benefits that **Aneet Narendranath** gleaned from using the Pi

Overhauling internal computer systems can be hard, especially in places where the systems are vital. In the case of Michigan Tech ELC, replacing a proprietary data collection system – used by students – with Raspberry Pi is looking to be not only cost-effective, but also an upgrade over an existing system, as Aneet Narendranath explains to us.

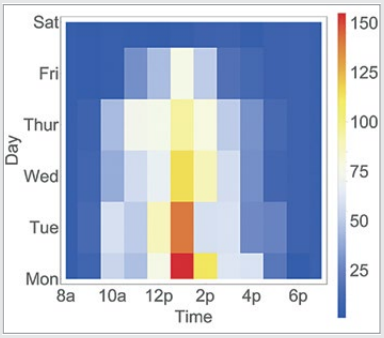
Below Data flow of the system that Aneet has successfully tested


Raspberry Pi: Reports will be auto-generated and available via ssh/ftp/webpage. Supplementary analysis code for MATLAB and Excel will be created for future.
python
SFTP
ssh
Student signs-in to receive help at ELC.
Student
Faculty coordinator
Excel

Can you tell us about your Pi data collection system?

At Michigan Tech as part of my responsibilities, I manage and direct the operations of the Engineering Learning Center (ELC). The ELC is an in-house tutoring resource that helps engineering students with concepts and concept applications for engineering problems that they encounter in homework assignments. The tutors in the ELC, who have the title 'coach', are students themselves. At the ELC, we use peer-to-peer instruction as a method of teaching and learning. The purpose of the ELC is to allow engineering problem resolution through concept discussion amongst peers.

At the ELC, I work with a certain yearly budget. The budget and the staffing of the ELC with coaches are coupled strongly. To ensure that we optimise our monetary resources through effective staffing, whilst ensuring that students receive help when they need it, is a (multidimensional mathematical)



Above This is a heat map of the ELC usage, processed on a Pi. It helps improve resource allocation

challenge. To perform this optimisation, we need (or needed) to collect ELC usage data to visualise what courses, hours of the day, and days of the week the ELC is used the most by students. By collecting data over several semesters, we found patterns in ELC usage and that allowed us to make staffing decisions, thereby helping us balance our budget while assisting students.

We have a proprietary 'Learning Center Management System' that we use currently. We are planning on replacing it with a Raspberry Pi-based (prototype) data collection alternative. In this Raspberry Pi system, data can be collected through an interface written in Bash and then analysed through Python and Octave scripts. This Raspberry Pi alternative is in its alpha version. The beta version will be deployed shortly.

How did the idea come about?
Our previous method of data collection, which was proprietary although effective, was not flexible and could not be automated for ELC-specific usage. This and its cost had us review other options. I have personally used the Raspberry Pi to keep track of my house when I am away on vacation (like an IoT device). Given that I had already used it extensively at home and am fairly comfortable with the Pi and Linux Bash and Python scripting, I thought, why not write some code that is deployed on the Raspberry Pi and would help understand ELC usage? It would collect student data through an interface and churn out reports in automated fashion, in a form and shape as decided by the needs of the ELC.

MICHIGAN TECHNOLOGICAL UNIVERSITY

Image credit: Jcvertin

As its name suggests, Michigan Tech is a university that started as a school for teaching engineering, specifically miners. Over the years the course topics have increased, so while there's still a bit of an engineering and science focus in the curriculum, you can also take courses in business, art, and social studies. Besides that, it's also a research university, so there's always a wide variety of research being done across the school at every level of learning.

Why the Raspberry Pi?
It is inexpensive but is still robust. For example, I have left my Raspberry Pi on, running this data collection code for 90 days with no issues. It allows for all the flexibility and power of a Linux computer, seeing as I run Raspbian.

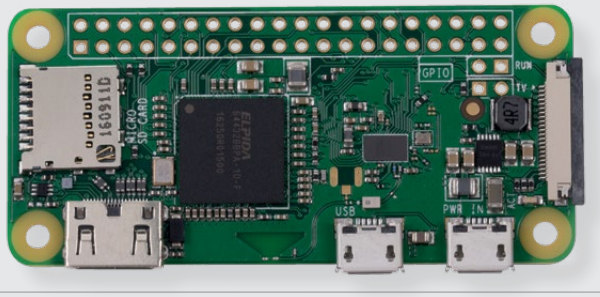
What hardware and software are you using?
I have several Raspberry Pi Zero Ws running Raspbian/Jessie or Lite. I also have a few Raspberry Pi 3Bs in the system. The data collection software is a Bash script. The data analysis and post-processing program was written in Python (with NumPy, Matplotlib, and Pandas) and Octave.

Have you had any interest from other universities?
No, this is a project that is internal to our mechanical engineering department for now. There has been some interest from other departments on-campus at my university.

Do you have any online resources for people who might want to build their own?
All of what I have is 'software based'. I will eventually have a Git page dedicated to this project that others can fork from.

The use of data-science tools to make staffing and optimisation decisions for our Learning Center is a relatively new venture. We hope to understand our Learning Center's usage better and be better prepared to help students. Learning Center staffing is a complex multidimensional problem, much like a complex 'job shop scheduling' problem. It is neat that we have an internally developed Raspberry Pi-based interface to collect and analyse data in an automated manner. The robust nature of the Pi, its flexibility and automation, and its cost are some of the main reasons that this is being deployed at our ELC.

Below Aneet has several Pi Zero Ws running Raspbian Jessie or Lite



THE MONTH IN RASPBERRY PI

Everything else that happened this month in the world of Raspberry Pi

CHRISTMAS TIME, MISSILE-BOTS AND WINE

HERE'S SOME OF THE INCREDIBLE THINGS THE COMMUNITY ARE MAKING AROUND CHRISTMAS!

As we write this issue slap-bang in the middle of December, members of the community are revealing their amazing Christmas-themed projects and Pi decorations. We love some special festive projects here at *The MagPi*, so here are some of our faves!

CHRISTMAS LIGHTS BOOKSHELF

magpi.cc/2B2uATV

Sometimes you have to work with what you've got, so we like the idea behind this LED-lit bookshelf with controllable colours. Useful at any time of the year, and festive when you want it to be.

ANIMATED XMAS TREE

magpi.cc/2B1XUKb

A fun little decoration by regular contributor Gareth Halfacree. We think it's cute and we also love the wooden frame – a perfect little geeky decoration to keep at your work desk, we say!

Gareth Halfacree
@ghalfacree
Following
Replying to @TheMagP1
Just re-purposed my @pimoroni Unicorn Hat powered home energy monitor into an animated Xmas tree, because why not?

3D XMAS TREE SNOW GLOBE

magpi.cc/2B1WhMv

We love The Pi Hut's 3D Xmas Tree kit, but we must admit we never thought about using it in this way! You probably shouldn't shake it, though, otherwise the Pi might fly around the enclosure.

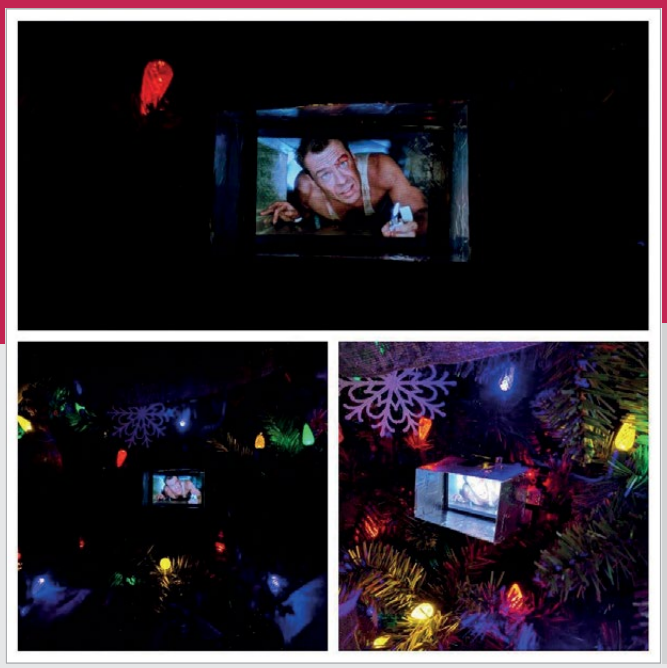
Wayne
@wkeenan
Following
Replying to @TheMagP1
My PiZeroW and @pihut XmasTree snow globe (snow machine and Sleigh Cam live stream yet to be turned on). May add a XmasTree Lights remote UI
0:01

TWITTER-ACTIVATED SNOW GLOBE

magpi.cc/2AZZFaC

Spencer Organ decided to let you control his snow globe. It looks out for specific keywords in his Twitter mentions and lights up accordingly! It's a great little visual reminder of incoming tweets and generally a lovely looking project!

S Organ
@makercupboard
Follow
I'm really excited to share my Christmas @Raspberry_Pi @TheMagP1 @pimoroni project. If I get a mention with snow, party or Christmas my snow-globe will respond with different lighting effects. Full details, build guide and code themakercupboard.space/projects/pi_fi ...
3:07 AM - 1 Dec 2017



DIE HARD TREE ORNAMENT

magpi.cc/2B1kAdC

Yes, we all know *Die Hard* is a Christmas movie. That battle has been won. Last year a viral image was making the rounds of a John McClane Christmas decoration, which was pretty fun, but reddit user rj45jack decided to take it one step further and make it with a Pi and a screen. It's a bit brighter that way.

KICKSTART THIS!

Raspberry Pi projects you can crowdfund this month

PITALK

kck.st/2Bf5EGg

This is a kit that will turn your Raspberry Pi into a smartphone! It's by SB Components, which has an excellent history of making top-quality Raspberry Pi kits, and we don't expect this to be any different. Due to the mobile data service integrated into it, you can easily use it for IoT applications for which you might not have WiFi access.

PI ZERO DOCKING HUB

kck.st/2zQpt5E

This nice-looking project also has a very succinct description: "The Pi Zero USB Docking Hub is a stackable USB hub that comes with five USB 2.0 data and charging ports, a micro USB port for power input, an RJ45 port for Ethernet, and a 3.5mm audio input/output jack. Installation would take only seconds."

BEST OF THE REST

Here are some other great things we saw this month

'ACCURATE' SNES EMULATOR

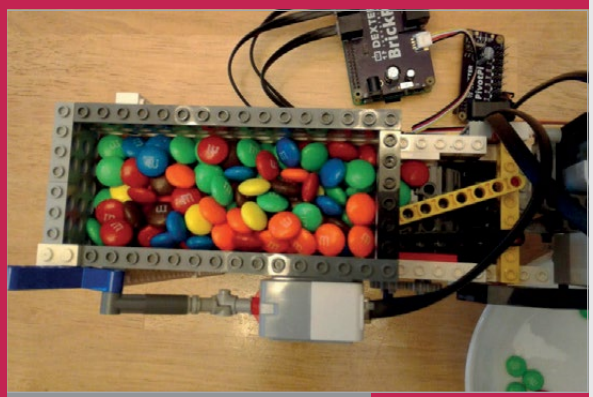
Emulation of Eighties and Nineties consoles on modern TVs can be very contentious due to how scanlines change the way games look. Raspberry Pis do have an analogue video out port, though, so Reddit user cadmiumredlight made use of that and installed a Pi 3 inside an old CRT TV. Perfect emulation.

magpi.cc/2ATFbjQ

ROOMBA-CHASING DRONE

Aldo Vargas built a drone that could visually identify and then automatically track a Roomba. Why? Well, the coding behind it is quite complicated, and it's a pretty cool achievement. Plus, the video looks amazing as the drone chases the Roomba around a pathway outside.

youtu.be/AyS2c6FTZ6E



M&M COLOUR SORTER

magpi.cc/2AUBZo7

Amazing. Don't like specific M&M colours? Instead of asking you 'why', we'll just point you towards the latest project from our friends at Dexter Industries: an M&M sorter. It melds chocolate with LEGO and Raspberry Pi, so it ticks every box imaginable.

REGISTERED FOR THE BIG BIRTHDAY WEEKEND?

HERE'S WHAT'S NEXT

The Raspberry Pi Foundation wants to put on a global celebration for its sixth birthday. Here's how you can help

For the past few years, the Raspberry Pi Foundation has held a community event in Cambridge around Raspberry Pi's birthday, where people have come together for a huge party with talks, workshops, and more. Now they want more people to have the chance to join in with the birthday celebrations next year, so they're going to be coordinating Raspberry Jams all over the world to take place over the Raspberry Jam Big Birthday Weekend, 3–4 March 2018. Already registered? Here's what you need to do next.

What do you need to do?

At this point, you should be looking for a venue, and aiming to book the date as soon as possible. Don't leave it too late, or you might have difficulty securing a location. If you need some advice on finding a venue, refer to the appropriate section in the Guidebook (**magpi.cc/2q9DHfQ**).

Once you've done that, you should create a sign-up page for your event (on Eventbrite, for example). Then you can submit your event to the Jam map (**rpf.io/jam**), and start to publicise it locally.

We're planning to produce some limited-edition 'tour' T-shirts for the Big Birthday Weekend and we'd like to include as many Jams as possible on the back print. To make sure your event gets included, submit your Jam to the map as soon as possible.

Stay connected

If you're not already a member, you might find it useful to join the Raspberry Jam community on Slack (**slack.com**), where Jam organisers share ideas and help each other. Just email **jam@raspberrypi.org** to request an invitation to join.

NEED HELP STARTING A JAM?

First of all, check out the Raspberry Jam page to read all about Jams, and take a look at our recent blog post explaining the support that we offer: **rpf.io/jam**.

If there's no Jam near you yet, the Raspberry Jam Big Birthday Weekend is the perfect opportunity to start one yourself! If you'd like some help getting your Jam off the ground, we've produced a free Raspberry Jam Guidebook full of advice gathered from the amazing people who run Jams in the UK. Download it from **magpi.cc/2q9DHfQ**.

If you have any further queries, email: **jam@raspberrypi.org**.

COMMUNITY PROFILE

CIRCUITBEARD

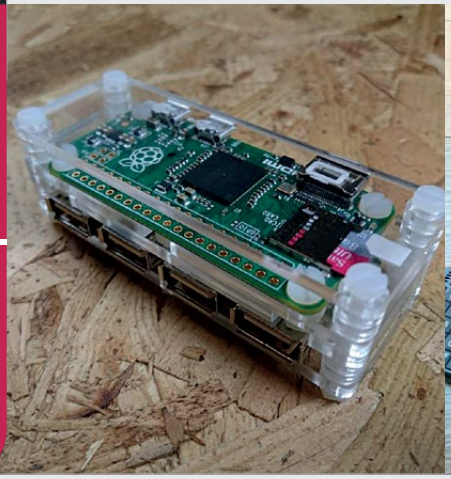
Web developer by day, resuscitator of retro technology by night. Meet **Matt 'Circuitbeard' Brailsford**

By day, Barnsley-based Matt Brailsford is the owner of Outfield Digital, a web development business where he spends his time creating sites using .NET CMS Umbraco. By night, he's Circuitbeard, toy hacker and nostalgia reigniter.

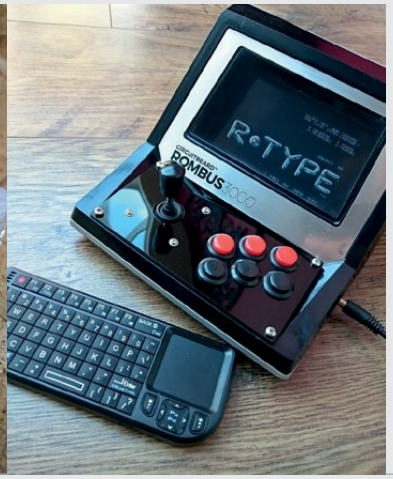
"I draw a lot of inspiration from my childhood and the tech and toys I used to play with as a child," Matt explains when discussing his hobby of hacking and upgrading old toys. "I find it fun to take things and reimagine them as they might have been had the original designers had the modern technology we have at our fingertips today."

The maker community became aware of Matt's hacking skills back in 2014 when a video of his NFC Spotify media server began to make the rounds across social media and news sites. "One of my first makes was a cassette player converted into a Spotify player, which used cassette tapes containing NFC tags to choose the playlist."

No stranger to the pages of *The MagPi* magazine, Matt's projects have been featured before, including his recent Out Run arcade game using the Tomy Turnin' Turbo Dashboard toy that was originally released in 1983. By implementing a new LCD screen and hijacking the controls for the original game, Matt was able to turn the toy into a game-emulating arcade machine. And it was a true test of his skills to create. "The project itself was quite a big one for me, filled with several moments



Below Inspired by Frederick Vandenbosch, Matt's Zero USB Hub is a neat and tidy means to easily access standard ports on the smaller board: **magpi.cc/2BiEgix**



Below By hacking a Grandstand Scramble machine to create the ROMBUS3000, Matt started his arcade building journey using hacked toys and parts: **magpi.cc/2zYPhoy**

Matt 'Circuitbeard' Brailsford

Category: Maker/hacker
Day job: Web developer
Website: circuitbeard.co.uk
twitter.com/circuitbeard
magpi.cc/2BiX1Of

Above Matt gained recent social media praise for his hack of a car toy to turn it into an Out Run arcade machine, complete with functional steering wheel

of frustration, from burnt-out potentiometers, to soldering LEDs backwards, multiple TFT screen purchases, and more…"

Alongside his Out Run project, Matt has also produced several bartop arcade machines, again taking their inspiration from past toys and tech. And, most recently, he took Google's AIY Projects voice assistant to a new level, installing it within the body of the iconic Tomy Mr Money. Lacking the Voice Kit given away by *The MagPi*, Matt decided to use the Pimoroni Speaker pHAT and a Raspberry Pi Zero W, both small enough to fit within the restrictive body of the money-eating gadget. "Rather than just creating a plain old box for it, I decided to repurpose another beloved '80s toy of mine."

Outside of his hobbyist workspace, Matt also runs a local makerspace in Barnsley, called Barnsley.IO, and travels to Maker Faires in order to meet other like-minded makers and explore future releases. And if hacking, website-building, and makespace management aren't enough for you, he's also working hard to produce Things Network, an open initiative to bring a free-to-use, long-range IoT network to his local community. "The hope is it will bring new opportunities to local businesses and open up a new era in digital manufacturing."

And as for the future? "I've got a few projects I'd like to build and some skills I'd like to improve," Matt reveals. Set to build his own mini pinball table, Matt would also like to work on his 3D-printing skills. "I've had one for a couple of years now and I've used it to build some components for my makes, but I've never really been impressed with my results."

Inspired by makers like Colin Furze and Love Hultén, and set to dial in his maker skills to produce more builds in 2018, we're excited to see where the future takes Circuitbeard.

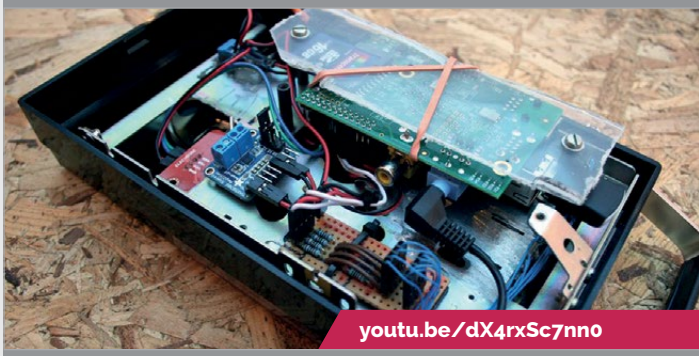
> "I draw a lot of inspiration from my childhood and the tech and toys I used to play with as a child"

PROJECT HIGHLIGHTS

magpi.cc/2zWRgSX

ROMBUS-CT COCKTAIL ARCADE

Matt's two-player ROMBUS-CT was inspired by a cocktail arcade cabinet video he came across online (**youtu.be/DuT_CHWoQ_M**). Using a fair bit of Pimoroni's Picade tech in the build, Matt was invited onto the company's YouTube show 'Bilge Tank' in 2016 to share his project with the world (**youtu.be/joaaF-yOnlY**).



youtu.be/dX4rxSc7nn0

SPOTIFY MEDIA SERVER

Matt's Spotify Media Server turned heads back in 2014 when a YouTube video for the build was shared across the tech world. NFC tags fitted within old cassette tapes direct the Raspberry Pi within to play specific Spotify playlists.

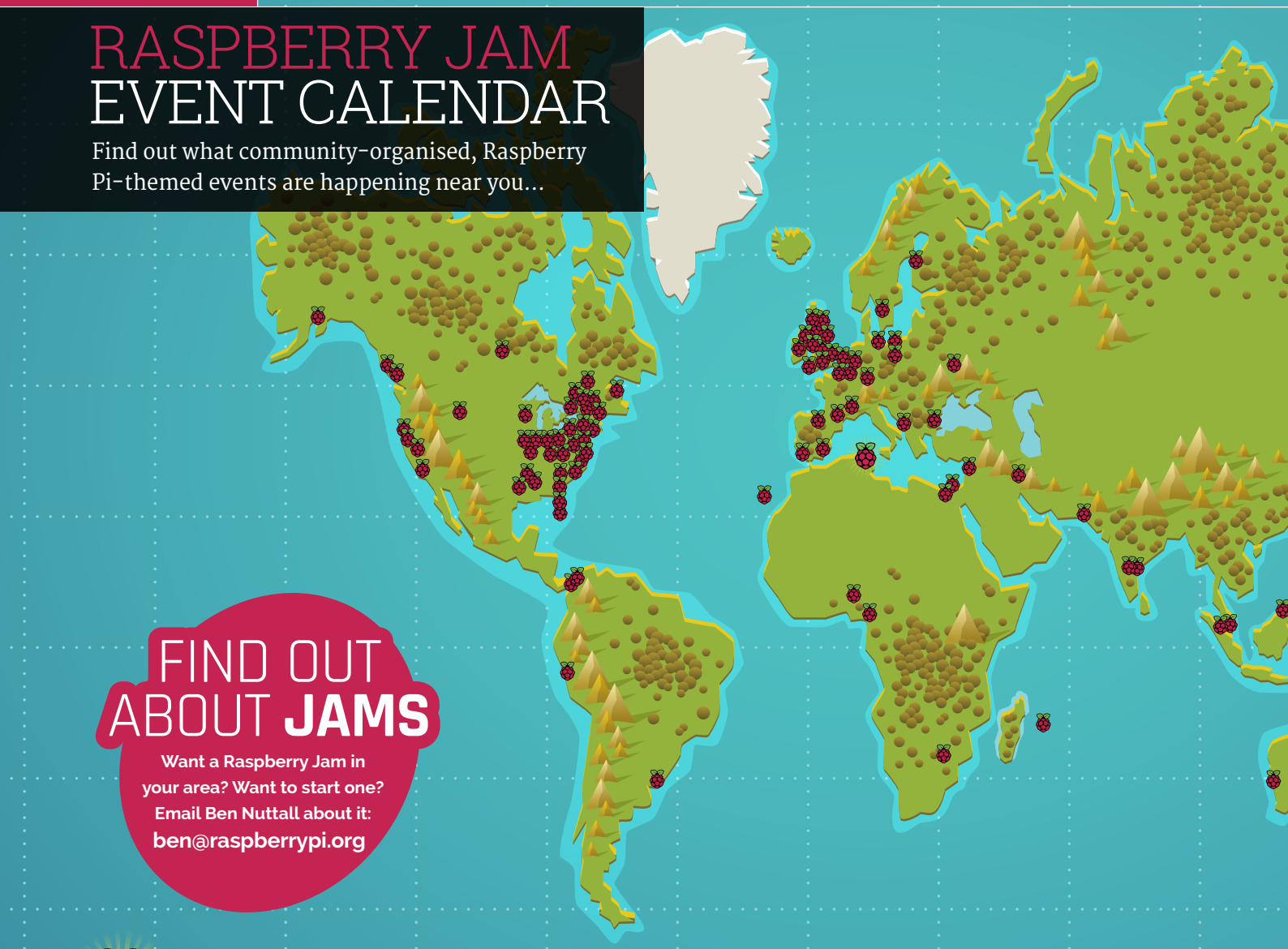
magpi.cc/2j9rYgA

MR MONEY GOOGLE AIY ASSISTANT

Fitting so much tech into a small container is always a challenge, but Matt somehow managed to cram a Pi Zero W, pHAT, speaker, and more inside his Tomy Mr Money. He even went so far as to alter the voice, raising the pitch to better suit the size of the little robot.

RASPBERRY JAM EVENT CALENDAR

Find out what community-organised, Raspberry Pi-themed events are happening near you...



FIND OUT ABOUT **JAMS**

Want a Raspberry Jam in your area? Want to start one? Email Ben Nuttall about it:
ben@raspberrypi.org

HIGHLIGHTED EVENTS

1 OXFORD RASPBERRY JAM

When: Saturday 27 January
Where: Oxfordshire County Library, Oxford, UK
magpi.cc/2Am2h3y
Whether you're a beginner, family, or a committed enthusiast, the Oxford Jam team would love to see you at their first Jam.

2 EXETER RASPBERRY JAM

When: Saturday 6 January
Where: Exeter Library, Exeter, UK
magpi.cc/2Be2TZ6
There will be lots to do, plenty of help and advice, and Pis to play with at the Exeter Raspberry Jam – head south-west!

3 PRESTON RASPBERRY JAM

When: Monday 8 January
Where: Media Factory Building, Preston, UK
magpi.cc/2Bct02L
Preston Raspberry Jam is a community of folk who meet each month to learn, create, and share the potential of the Raspberry Pi.

4 SWAB PI INTEREST GROUP

When: Wednesday 10 January
Where: Roebuck Pub, Winchester, UK
magpi.cc/1PgyqaY
The Southampton, Winchester, Andover & Basingstoke Pi Interest Group is a relaxed event for playing around with Pi.

REGULAR EVENTS

5 CORNWALL TECH JAM

When: Saturday 13 January
Where: Penwith College, Penzance, UK
cornwalltechjam.uk
For anyone interested in technology, of all ages and abilities. Ask questions and learn about programming in Scratch, Python, Minecraft, and much more.

6 MANCHESTER RASPBERRY JAM

When: Saturday 13 January
Where: The Shed, Manchester, UK
magpi.cc/2AlS7QA
Through this event, the hope is to share the excitement of technology with the programmers, engineers, and makers of the future.

7 COTSWOLD RASPBERRY JAM

When: Saturday 27 January
Where: Park Campus, Cheltenham, UK
cotswoldjam.org
Taking place at the University of Gloucestershire, this event showcases the Raspberry Pi computer and helps people to learn all about it.

8 HULL RASPBERRY JAM

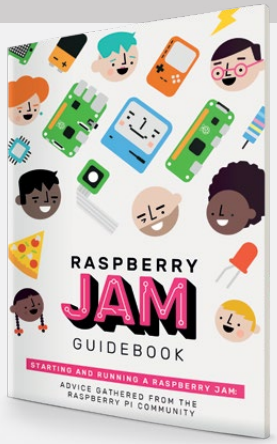
When: Saturday 27 January
Where: Hull Central Library, Hull, UK
magpi.cc/2AlbDNb
There'll be chances to get hands-on with more digital making activities through workshops and a hackspace area to share projects and give lightning talks.

RASPBERRY JAM ADVICE

PLANNING THE ACTIVITIES

> "We tend to visit other Jams to see what inspires us. We then approach that person to come and run the same workshop at our Jam. As time goes on, we will try to focus more on children giving the workshops."
>
> **Marcus Tyler-Moor**
> **Horsham Raspberry Jam**

Every Raspberry Jam is entitled to apply for a Jam starter kit, which includes magazine issues, printed worksheets, stickers, flyers, and more. Get the guidebook here: **magpi.cc/2q9DHfQ**



YOUR LETTERS

MAGAZINE GIVEAWAYS

I've been thinking of getting a subscription to *The MagPi*. However, I had a few questions about your special giveaways like the AIY Projects kit. First of all, do these special issues cost extra as part of the subscription? Also, how often do you do them?
Timothy R

Nope Timothy, all of our giveaways on special issues have been free and included with the standard price of the magazine. This means whether you buy them in a shop, online, or if you subscribe. We don't have a set schedule for giveaways on the mag and a lot depends on outside factors beyond our control. However, we always want to do more of them in the future where we can.

Subscribing is also a great way to help support the Raspberry Pi Foundation, as all our profits are sent directly to them so they can continue their charitable mission!

DONATING OLD MAGPIS

I saw the letter in the November issue about recycling old copies of *The MagPi* to go to makerspaces and such.

I help organise the Riverside Raspberry Pi user group in Riverside, CA. We probably don't have the funds to pay for shipping, but I would like to build a library of *The MagPi* issues for use by our members (any duplicates would be made available to our members to keep for free). So if you have people willing to ship them, we would gladly accept them.

Depending on the response you got from this post, I could see there being many people wanting to donate, so maybe connecting us up to a select number of people might be a good idea.

Let me know what your thoughts are on this.
Brian

Since our initial letter in the magazine, you're the first person to contact us about this, Brian. Unfortunately, we've had no offers from other people with used or unwanted issues, so we're unable to help you with getting some issues at this time.

However, we've started up a thread on the forum to try to encourage people to donate issues of *The MagPi* if they have any spare. At the moment it's an experiment, but do take a look on there and see if people are offering anything: **magpi.cc/2BB4yZ1**.

Raspberry Pi resources

I've recently begun showing people the Raspberry Pi and how to use it. I really want to expand my repertoire on what I can demo with the Raspberry Pi, and any extra materials I can then send people so they can learn more. I don't suppose you could send us any spare issues of the magazine? Otherwise, what kind of resources can I find online?
Karen

Unfortunately, Karen, we don't get enough spare physical copies to do that. However, every issue of *The MagPi* is available for free online as a PDF. You can always get them printed it off if you want, or at least your favourite tutorials.

As for other resources, the Raspberry Pi Foundation has a ton of free learning resources on its website, which you can find here: **magpi.cc/1qEg9Nh**.

There's a lot of free learning to be had for the Raspberry Pi – take a look at these and see if there's anything worth giving folks you're showing the Pi off to!

Above It's easy to get started with Raspberry Pi using our guides and online learning resources

FROM THE FORUM:
AIY PROJECTS VISION KITS IN THE UK

WRITE TO US

Have you got something you'd like to say?
Get in touch via **magpi@raspberrypi.org** or on The MagPi section of the forum at: **raspberrypi.org/forums**

The Raspberry Pi Forum is a hotbed of conversations and problem-solving for the community – join in via **raspberrypi.org/forums**

I was just reading *The MagPi* and I am really wanting the AIY Vision Kit! However, where will I be able to buy the kit in the UK? The AIY Voice Kit is only available for in-store pick-up, so I am presuming the Vision Kit will be the same. Even if it is available for delivery, it will probably cost a fortune to ship it to the UK.
KanoMaster22

For the moment, the AIY Vision Kit is only be available from Micro Center, in the US. We know Google is planning to make more Vision Kit devices available in the next few months, and these will be available across the EU (including the UK). Make sure to pay attention to the mag to know when the kits go on general sale. Also, sign up to our mailing list so we can let you know as soon as possible: **magpi.cc/Email-me**.

The new AIY Vision Kit is a smart camera, and a sibling kit to the Voice Kit that was included with issue 57

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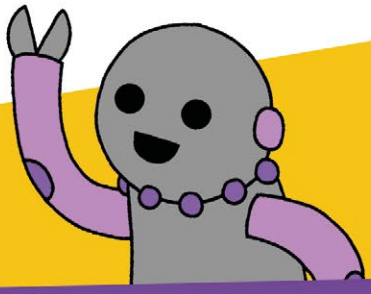
{code club}



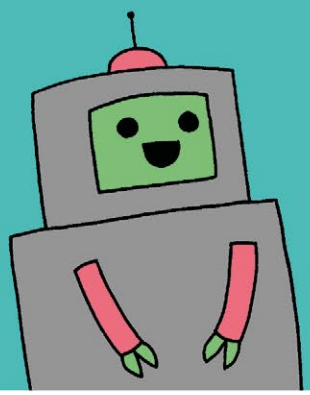
START A CODE CLUB IN YOUR SCHOOL!

Code Club is a network of volunteers and educators who run free coding clubs for young people aged 9-13.

Our aim is to inspire the next generation to get excited about computer science and digital making.

"We use Code Club's fun educational resources to run a weekly after-school club for Year 7 and Year 8 pupils. The students benefit considerably from the extra challenge!"

Karen Dadd, Computing Teacher



- **Code Club is free**
- **Code Club provides step-by-step guides for Scratch, Python, HTML, and Sonic Pi**
- **Code Club helps children develop skills including logical thinking, creativity, and resilience**

We have over 6000 clubs across the UK teaching more than 80,000 young people to code—come and join us!"

Find out more at www.codeclub.org.uk

Code Club is part of the Raspberry Pi Foundation. Registered Charity Number 1129409

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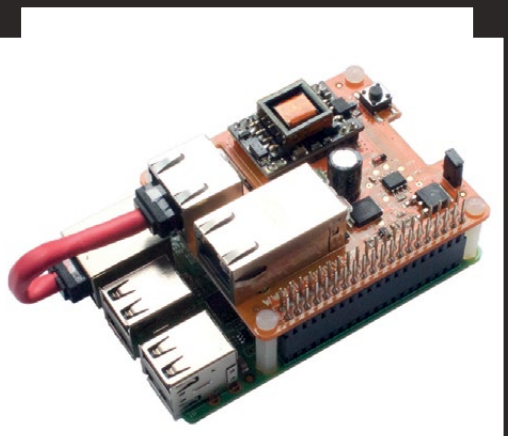


Three runner-up winners will get!

- Pi PoE Switch
- Pi PoE Case

Plus! Three more runner-up winners will get!

- PoE Switch HAT

Enter now at magpi.cc/WinJan18

Terms & Conditions

Competition opens on **20 December 2017** and closes on **25 January 2018**. Prize is offered to participants worldwide aged 13 or over, except employees of the Raspberry Pi Foundation, the prize supplier, their families or friends. Winners will be notified by email no more than 30 days after the competition closes. By entering the competition, the winner consents to any publicity generated from the competition, in print and online. Participants agree to receive occasional newsletters from The MagPi magazine. We don't like spam: participants' details will remain strictly confidential and won't be shared with third parties. Prizes are non-negotiable and no cash alternative will be offered. This promotion is in no way sponsored, endorsed or administered by, or associated with, Instagram or Facebook.

MATT RICHARDSON

Matt Richardson is the Executive Director of the Raspberry Pi Foundation North America and author of *Getting Started with Raspberry Pi*. Contact him on Twitter @**MattRichardson**.

THE LAY OF THE LAND

Matt Richardson welcomes new users to the Raspberry Pi community

Now that it's Christmas, a lot of people will find Raspberry Pis in their stocking or under the Christmas tree. And that means a lot of new users will join our community. If you're among that group, I'm happy to welcome you to the world of Raspberry Pi! You're joining a massive community of enthusiasts with a wide range of skill levels, from complete beginners to computer experts. And there are so many possible ways to use Raspberry Pi that entering this community could feel a little daunting at first. I want you to feel comfortable as a new Raspberry Pi community member, so let me give you the lay of the land.

Whether you plan to use our affordable computer for a particular project that you already have in mind or you hope to experiment and improve your computer skills, there's no shortage of support and inspiration out there. The fact that you're reading *The MagPi* is a great first step. Every month, you'll receive a well-curated selection of projects, community member profiles, and news from the Raspberry Pi community. I should point out that every issue of *The MagPi* is available as a free PDF download, so there's a huge catalogue of content to browse when you're looking for inspiration.

If you need a daily fix of community updates, then be sure to check out the Raspberry Pi blog, which is featured at the top of **raspberrypi.org**. You can also stay up to date with us throughout the day by following the Raspberry Pi Foundation on Twitter, Facebook, YouTube, and Instagram. If you prefer email updates, then subscribe to Raspberry Pi Weekly, which is a digest of the week's news delivered straight to your inbox.

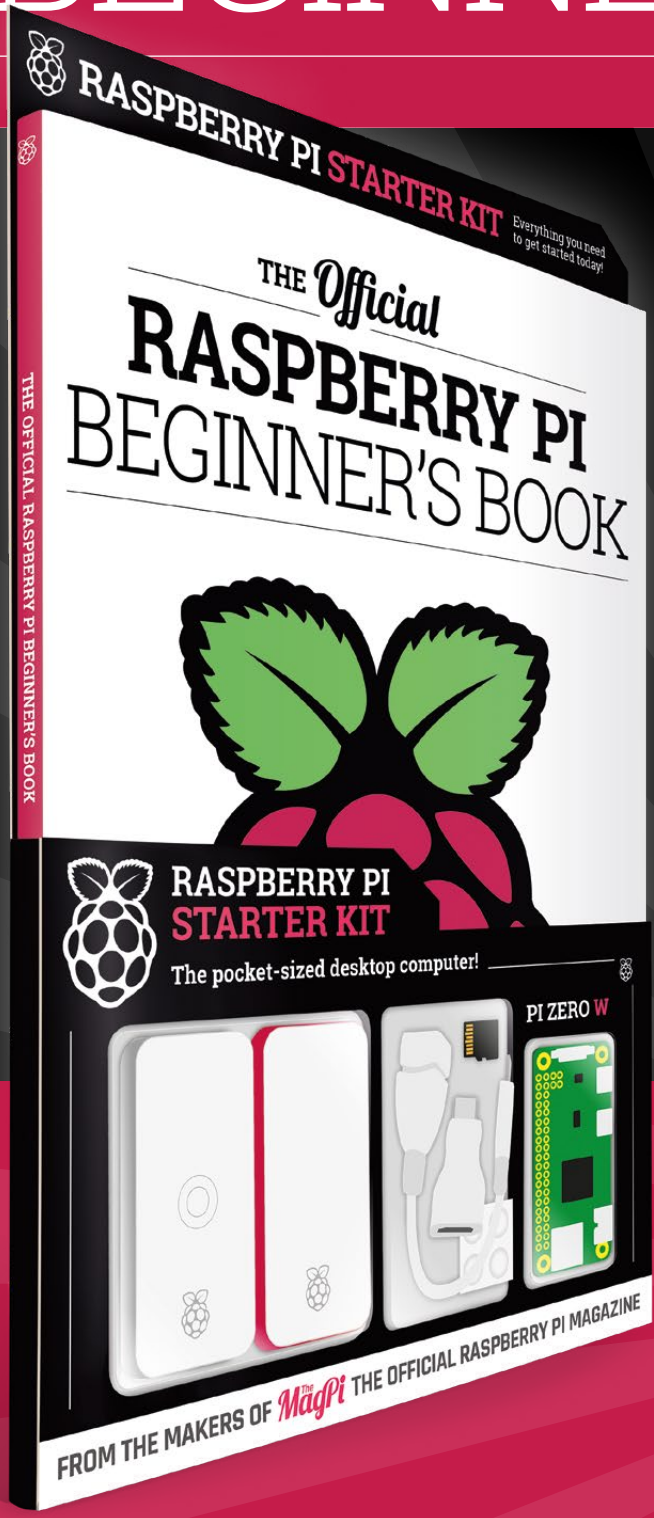
For those of you who want to make and learn, we have a large collection of projects at **projects.raspberrypi.org**. These step-by-step guides are categorised by topics such as games, jokes, photography, and robots. They're designed with learning in mind, so they don't just tell you what to click or what to type. They guide you through the process of making a project, but they challenge you at the same time. Hints are available throughout the projects so although you'll be challenged, you'll never get stuck. These projects are the best way to explore the concepts of computing and digital making.

If you run into any trouble getting started with the Pi, the Raspberry Pi forums are where you should turn for support. There are tons of community members who help each other out there. Keep in mind that there are over one million posts in the forum, so run a quick search before you post your own question… chances are someone has asked the exact same thing that you're trying to figure out.

And our community members don't only meet online. They also get together in person at Raspberry Jams. These community-led events take many different forms, from just a few people meeting together to very large events with hundreds of people. To find a Jam near you, or to start your own, go to **raspberrypi.org/jam**.

As you'll learn, the world of Raspberry Pi is a massive one, but it's rich with quality content, a supportive community, and no shortage of inspiration. I'm delighted to welcome you here and I hope you'll show the rest of the community what you make with Raspberry Pi. Merry Christmas and a very Happy New Year!

THE *Official* RASPBERRY PI BEGINNER'S BOOK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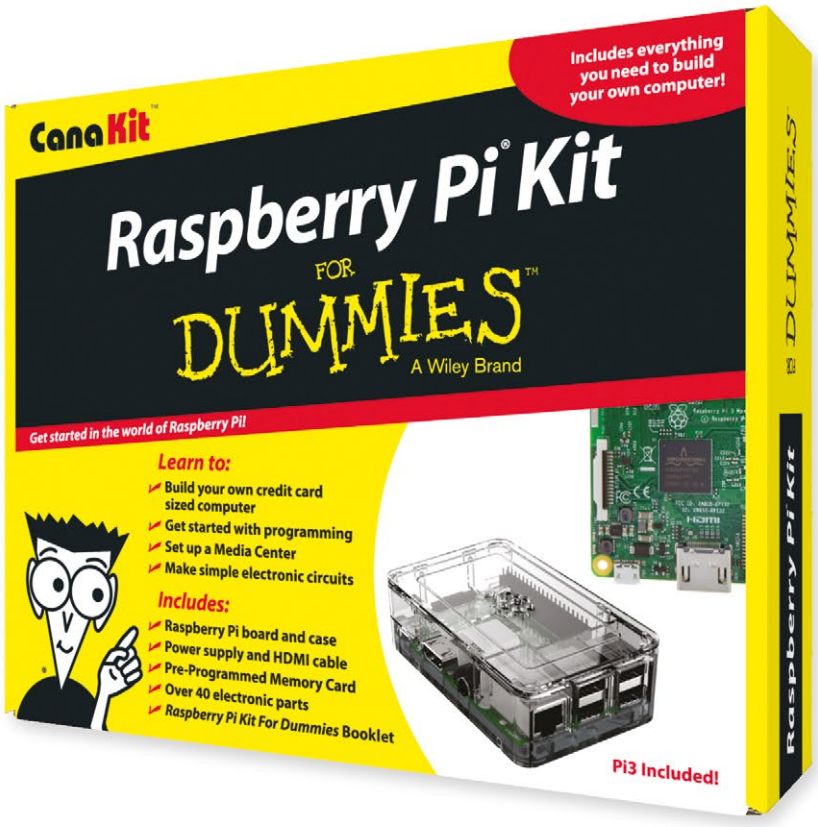

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